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# EARLY DEVELOPMENTAL STAGES OF THE HUMAN LUNG

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## INTRODUCTION

The lung appears to be the last of the large organs of the human body about which a complete unquestioned embryological story has been built. In fact, the origin of the lung may be said to be as yet rather obscure.

In the latter part of the last century the theory was clearly expounded by Kölliker (1), Aeby (2) and His (3) that the entire lower respiratory passage (from larynx outward to and including the alveoli) arises as a diverticulum of the foregut.

This idea has led to much investigation in recent years and some doubt has been expressed as to its accuracy. From various observations a second theory has been developed which states that the lung may have a dual origin, such as has been shown to be the case in the kidney (Rose (4), Policard (5), Terni (6)). It has been postulated that the larynx, trachea, bronchi, bronchioles, and the part of the respiratory bronchioles lined with cuboidal epithelium arise from the foregut diverticulum while the remainder of the respiratory bronchioles, the alveolar ducts, alveolar sacs and alveoli arise from the mesenchyme into which the diverticulum branches. Assuming this theory to be true, the mode of union of these two embryonic components to form the completed tracheo-bronchial tree has never been demonstrated.

His (3), Narath (7), Merkel (8) and Blisnianskaja (9) carefully described the lungs in the human embryo but their accounts did not trace the development very far into the period of the foetus (third to ninth months inclusive). Thus there seems to be a need for more descriptions of developmental stages of the human lung. These studies are being made with

the idea that the nature of the tracheo-bronchial tree may be elucidated by tracing its development in a series of human embryos and foetuses. The lungs described in this paper complete the study to the 118 mm. C. R. stage. The first five specimens have been selected to form a well-spaced series as to crown-rump length. The original idea of continuing this rather close-spaced series was dropped because it appears that the description of lungs in the third month of prenatal development (foetuses from about 25 to about 75 mm. C. R. length) would only be a recitation of the continued growth of the epithelial anlage described in the first and second months of prenatal development. For a stage in the fourth month, a specimen was selected that shows excellent tissue fixation and that has a complete history. The menstrual age of this foetus was 109 days and the C. R. length is 118 mm.

In a recent paper the author (12) has rather fully described the human foetal lung at the 152 mm. stage (in the fifth month). The heart of this foetus beat for some minutes after delivery but there were no respiratory movements. The tracheo-bronchial tree at this stage has a continuous intact lining of epithelium and the maximum number of generations of tubules forming the tree is seventeen. The lining of the terminal tubules was a light-staining cuboidal epithelium, enclosing a small lumen.

The author is satisfied that a description of further stages in the gaps between 35 and 118 mm. C. R. length and between 118 and 152 mm. C. R. length would not add any essential facts to the story, and feels warranted in drawing the conclusion that the human tracheo-bronchial tree as found in the 152 mm. C. R. stage is entirely a product of the foregut entoderm. If there is a contribution from the mesenchyme to the human tracheo-bronchial tree it does not occur before the 152 mm. stage.

## MATERIAL AND METHODS

The embryos that are described in this paper were selected from a large group on the basis of gross and microscopic appearance. The specimens were carefully measured in the crown-rump (C. R.) axis before sectioning. These measurements were:

| | |
|---|---|
| Embryo I | 11 mm. |
| Embryo II | 15 mm. |
| Embryo III | 19 mm. |

| | |
|---|---|
| Embryo IV | 23 mm. |
| Embryo V | 35 mm. |
| Embryo VI | 118 mm. |

The specimens were fixed in formalin, imbedded, sectioned, mounted serially and stained routinely.

Wax reconstructions of the gross lung, of the complete tracheo-bronchial tree in Embryos II and IV, and of portions of the tree in the other specimens were prepared by projecting the sections on wax plates of the appropriate thickness. An Edinger projection apparatus was used.

## A. MORPHOLOGY OF THE GROSS LUNG

Length of the Lungs: These measurements were taken either from the apex (superior pole) to the inferior pole as in Embryos I-IV, or from the apex to the posterior margin of the base as in Embryos V and VI.

| | Right Lung | Left Lung |
|---|---|---|
| Embryo I | 0.70 mm. | 0.60 mm. |
| Embryo II | 1.43 | 1.20 |
| Embryo III | 1.80 | 1.70 |
| Embryo IV | 2.08 | 1.80 |
| Embryo V | 5.08 | 5.24 |
| Embryo VI | 14.20 | 15.10 |

### Right Lung (Plate I)

At the 11 mm. stage the right lung is an elongated loaf-shaped mass, flattened dorso-ventrad. At the 15 mm. stage the superior portion of this mass is the more bulky; the whole lung is the shape of an inverted pear. During the period from the 15 to the 35 mm. stages a sloping basal surface develops to replace the pointed inferior pole. As a result the shape of the right lung, while still piriform, is reversed, since the base of the pear is now downward. The sterno-costal surface of the right lung presents elevations at both the 11 and 15 mm. stages. During the 15 to 19 to 23 mm. intervals these elevations disappear over the superior and middle lobes, but traces of them are still present on the inferior lobe at the 35 mm. stage. By the time of the 118 mm. stage the right lung has the adult form, with entirely smooth surfaces.

#### Lobes and Fissures

1. *Superior Lobe.*—The anlage of the superior lobe at the 11 mm. stage is an ovoid lobule which faces dorsolaterad and which is incompletely separated from the anlage of the middle lobe. The groove partially separating these two lobes begins dorsad at the anlage of the oblique fissure and as the two lobes grow, extends ventrad. The superior lobe forms but little of the anterior border of the lung until the 19 mm. stage. From this latter stage to the 35 mm. stage, the superior lobe grows to a more anterior position. In effect, the superior lobe is rotated ventrad along the circumference of the inside of the thoracic wall during the 19–35 mm. interval, by the development of the inferior

lobe below and behind it. Meanwhile the superior lobe itself is growing and expanding laterad (Plate I). It appears that the superior lobe which arises from a more orally located portion of the right primary bronchus than do the middle and inferior lobes, is more mature than these latter lobes. The superior lobe at first grows dorso-laterad, then laterad and finally antero-laterad.

2. *Middle Lobe.*—The anlage of this lobe at 11 mm. is an incomplete lobule that faces directly laterad. By the time of the 15 mm. stage the lobule has grown ventrad to help form the anterior border of the lung. In the succeeding stages the middle lobe becomes relatively more inferior in position as the superior lobe develops above it, and more anterior in position as the inferior lobe develops below it. At the 35 mm. stage the superior lobe overhangs the middle lobe, but by the 118 mm. stage the middle lobe has become relatively larger in outline and more bulky, establishing the adult form. Thus it appears that the middle lobe grows at first directly laterad, then is carried downward by the growth of the superior lobe and rotated forward by the increasing mass of the inferior lobe. Finally, the middle lobe comes to lie in the angle between these two lobes. The adult position is inferior (in addition to anterior) because the superior lobe is more mature and bulky at each developmental stage than the middle lobe (Plate I).

3. *Inferior Lobe.*—At the 11 mm. stage the inferior portion of the loaf-shaped right lung represents the anlage of the inferior lobe. It is incompletely separated from and partly surrounds the middle lobe but is more completely marked off from the superior lobe. There are four elevations on the anlage of the inferior lobe, namely: one superior and dorsal, one superior and ventral, a third inferior and lateral and the fourth forming the inferior pole. At the 15 mm. stage the inferior lobe is more elongated and lies entirely inferior to the superior and middle lobes. The inferior pole has become more pointed. By the time of the 19 mm. stage the lower pole is being replaced by a surface. The posterior margin of this new surface is still sharply pointed. At the 23 mm. stage a sloping basal surface is present, and the lobe as a whole is pyramidal in shape with the apex at the superior end. The sterno-costal surface still presents elevations. These elevations are indistinct at the 35 mm. stage, and by the time of the 118 mm. stage the lobe with all surfaces smooth is a miniature of the adult inferior lobe.

4. *Oblique Fissure.*—At 11 mm. this fissure is represented by an incomplete and shallow groove. The anterior portion of this groove lies almost horizontal. By the 15 mm. stage this groove is much deeper, extends downward and forward, and makes a 30 degree angle with the horizontal. At the 15 and 19 mm. stages the oblique fissure is deepest at the point of junction with the transverse fissure. At the 23 mm. stage the oblique fissure makes a 45 degree angle with the horizontal due to the fact that the superior and middle lobes are farther developed than the inferior lobe at this stage. By the 35 mm. stage the oblique fissure is complete.

5. *Transverse Fissure.*—At 11 mm. the transverse fissure appears as a short groove extending from the anlage of the oblique fissure a

short distance ventrad and slightly upward. The fissure is complete at 15 mm. and at both this stage and at 19 mm. is deep in its posterior portion and shallow toward the front. By the time of the 23 mm. stage the *transverse* fissure is almost in that position, due to the rapidly increasing bulk of the superior lobe. This latter fact also accounts for the finding that the plane of the transverse fissure at the 35 mm. stage is directed upward as well as mesiad from the surface. In other words, the superior lobe overhangs the middle lobe. By the 118 mm. stage adult relationship has been developed.

### Left Lung (Plate II)

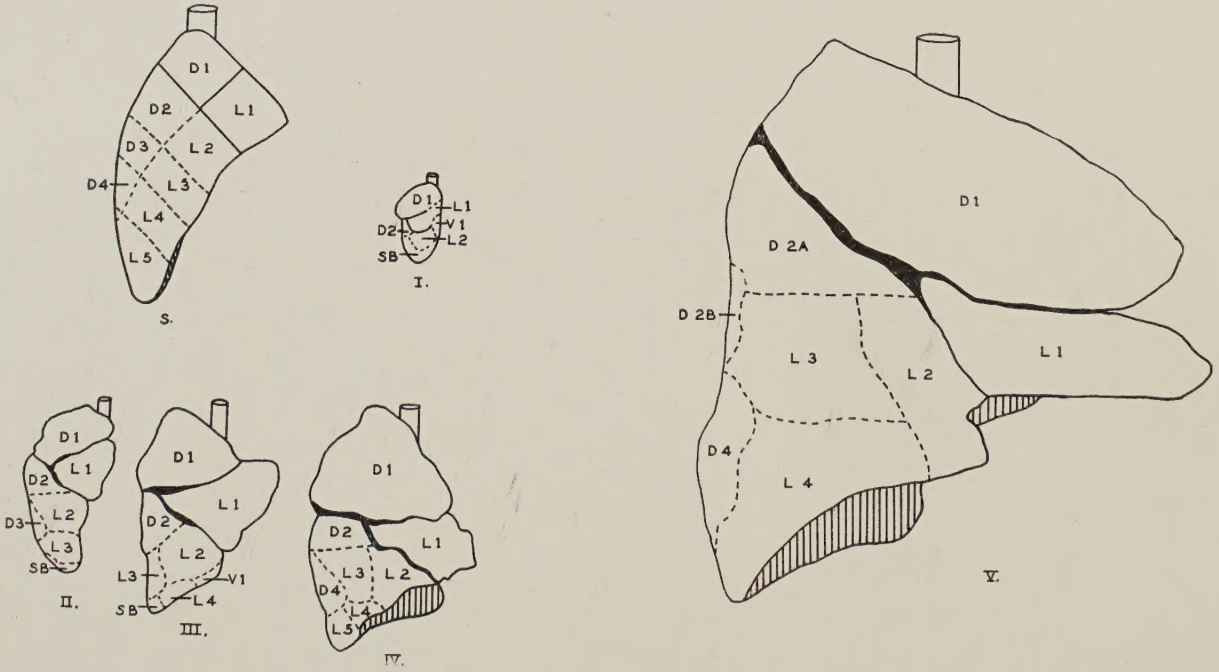
During the first two months of prenatal life the left lung is less elongated than the right, but early in the third month the situation is reversed, the left lung becoming and remaining the longer. In contrast to the six elevations on the right lung anlage at the 11 mm. stage, only five elevations are seen on the left lung. At each stage of the growth period under study, the superior lobe appears more mature than does the inferior lobe.

#### Lobes and Fissures

1. *Superior Lobe.*—The anlage of the superior lobe at the 11 mm. stage is an ovoid mass consisting of two conjoined lobules, a larger dorsal and a smaller ventral. These lobules are demarcated by a faint sulcus which is still present at the 19 mm. stage. At the latter stage the two lobules are of about equal size. At the 23 mm. stage the lobules are no longer distinct and the area corresponding to the ventral lobule is again smaller than the dorsal area. The groove between these two areas is very shallow at both the 23 and 35 mm. stages. At the latter stage a cardiac notch is present on the anterior border. At this stage this border and its notch lie directly lateral to the heart rather than anterior to it. At the 118 mm. stage the left superior lobe is a miniature of the adult specimen, with the exception of an incomplete fissure extending backward from the anterior border. This fissure begins just above the cardiac notch and extends backwards for 6 mm. but does not meet the oblique fissure. This additional fissure is to be regarded as an abnormality and not as a structure peculiar to the left superior lobe at the 118 mm. stage.

2. *Inferior Lobe.*—At the 11 mm. stage the anlage of the inferior lobe is an ovoid mass presenting three elevations, namely: a dorsal, a ventro-lateral and one formed by the lower pole. The depressions between these elevations are less distinct than those on the right inferior lobe at this stage. During the 11 to 19 mm. interval these elevations remain and enlarge, the entire inferior lobe becoming more bulky and less pointed at the inferior pole. At the 19 mm. stage there is only a slight indication of a basal surface. At 23 mm. an almost horizontal basal surface is developing. At 35 mm. the basal surface slopes farther downward in its posterior portion and the depressions and elevations on the sterno-costal surface are but faintly indicated. At 118 mm. the inferior lobe with all surfaces smooth has the adult form.

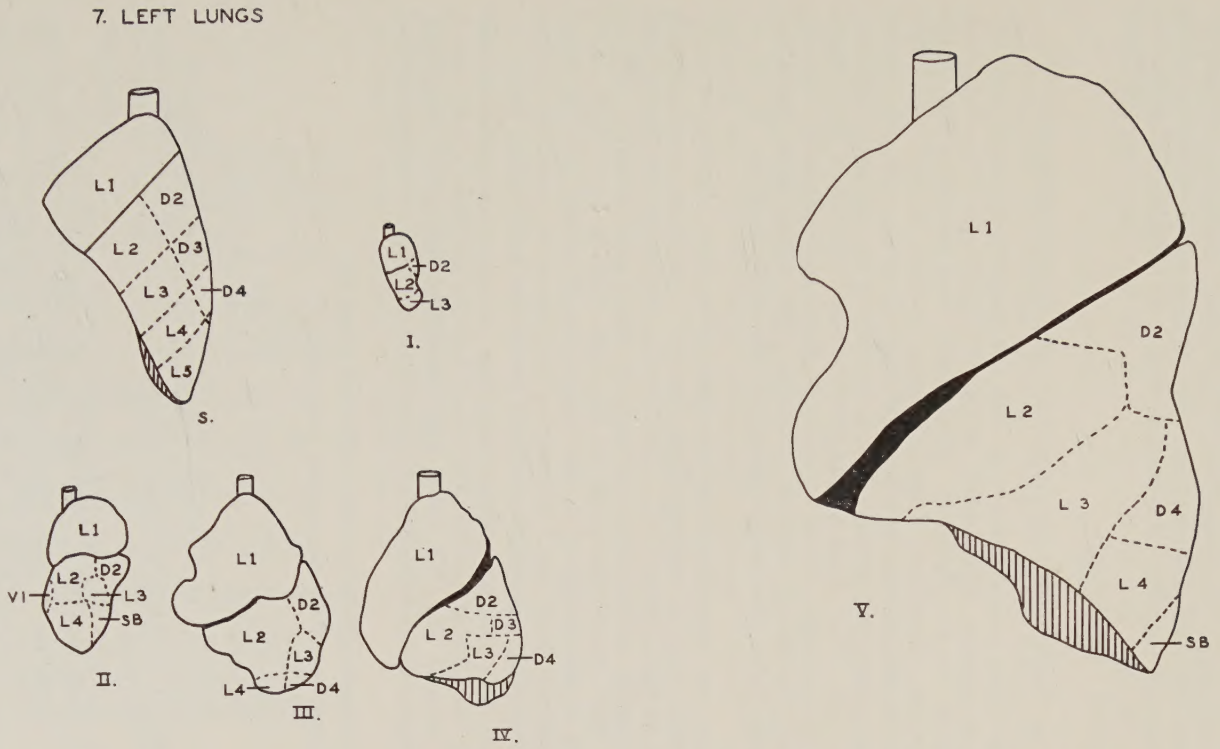
6. RIGHT LUNGS




Schemata of the lateral aspects of reconstructions of the right lungs of Embryos I, II, III, IV and V, showing the areas supplied by the branch bronchi of the right stem bronchus. For comparison a schema (S) of the lobation of the lung, modified from Narath (7) is shown.

KEY: Margins and sulci—thin lines; fissures—heavy lines; plotted areas of branch bronchi distribution—dotted lines; diaphragmatic surfaces—parallel lines.

D1, D2, etc.—dorsal branch bronchi; L1, L2, etc.—lateral branch bronchi; V1—ventral branch bronchus; SB—stem bronchus.




Schemata of the lateral aspects of reconstructions of the left lungs of Embryos I, II, III, IV and V, showing the areas supplied by the branch bronchi of the left stem bronchus, compared with a schema (S) of the lobation of the lung modified from Narath (7).

KEY: Same as for Plate I.

3. *Oblique Fissure.*—At 11 mm. the anlage of the oblique fissure is almost horizontal. It is relatively deep except in its dorsal portion. At 15 mm. this fissure is complete. At 19 mm. its posterior portion is more obliquely placed. The oblique fissure is complete in respect to depth at 23 mm., and by the time of the 35 mm. stage has the adult relationships. (Plate II.)

### B. TYPE AND DISTRIBUTION OF BRANCH BRONCHI

As the stem bronchi grow out into the mesenchyme and form the early lung anlagen, lateral buds known as branch bronchi arise from the walls of the stem bronchi. These buds may extend in any of the four principal directions, dorsal, lateral, ventral or medial. Those arising from the lateral aspect of the stem bronchus are the largest and most important group. These bronchi were termed "ventral" by Abey (2). They later extend more ventrad to supply the ventral portion of the lungs. However, His (3), Robinson (10) and Flint (11) term them "lateral or external" bronchi. The second most important group arise from the dorsal aspect of the stem bronchi. These are known as "dorsal" bronchi. Each dorsal bronchus (or group of dorsal bronchi in case more than one bronchus arises close together) usually arises orally to the corresponding "lateral" bronchus together with which it forms a "lung tier." The bronchi arising on the medial and ventral aspects of the stem bronchi are small and irregular. When present they are incorporated in the lung tier of that level. One exception to this statement is that one of the "ventral" bronchi found in the second "lung tier" is large. This has been called the infracardial bronchus. It usually becomes prominent in the right lung.

In the descriptions of these lungs the following nomenclature will be used: Dorsal bronchi (D1, D2, etc.); Lateral bronchi (L1, L2, etc.); Ventral bronchi (V1, V2, etc.); and Medial bronchi (M1, M2, etc.). In all cases a bronchus labelled (1) arises orad to a bronchus labelled (2) etc.

The patterns of the tracheo-bronchial trees are:

Branches of the right stem bronchus:

Embryo I—D1, L1, D2, V1, L2.
Embryo II—D1, L1, D2, L2, D3, L3.
Embryo III—D1, L1, D2, V1, L2, M1, L3, L4.
Embryo IV—D1, L1, D2, V1, L2, L3, D4, L4, L5.
Embryo V—D1, D2a, L1, D2b, V1, L2, L3, D4, L4.

Branches of the left stem bronchus:

Embryo I—L1, D2, L2, L3.
Embryo II—L1, D2, V1, L2, L3, L4.
Embryo III—L1, D2, L2, L3, M1, D4, L4.
Embryo IV—L1, D2, L2, D3, M1, D4.
Embryo V—L1, D2, L2, L3, D4, M1, L4.

No study was made of the tracheo-bronchial tree of Embryo VI.

A lateral view of the distribution of these branch bronchi is depicted in Plates I and II. It may be noted that the right stem bronchus of

Embryo II is the only stem bronchus that has a schematic distribution of branches; that is, it is the only stem bronchus from which the branches arise in an alterating pattern, first a dorsal branch bronchus, then a lateral branch bronchus. The other stem bronchi present a variety of patterns.

### C. THE GENERATIONS OF BRONCHI

The determination of the exact number of generations of tubules present in the tracheo-bronchial tree, even in a very young embryo is a difficult problem. It is fairly well agreed that new tubules may arise by any one or by combinations of three methods, namely, lateral budding (monopodial), dichotomous branching and trichotomous branching. No definite regularity in the occurrence of these methods of tubule formation in the growing tree has been described. Furthermore, in examining an embryological specimen it should be remembered that the growth processes may have obscured the forms of earlier stages. A dichotomous branching may later appear to be a larger bronchus giving off a smaller side branch due to the more rapid growth of one of the pairs of bronchi previously formed by the dichotomous division.

In a previous paper (12) the author has described a method of estimating the number of generations present at any stage in the development of the tracheo-bronchial tree. This method requires the making of a wax reconstruction from serial sections of the lung.

In brief the method of enumeration is as follows: The primary bronchus is followed until its first branch is encountered. Then this branch bronchus is designated generation 2 and it is followed to the origin of its first branch. Now this branch is designated generation 3 and it is followed to the origin of its first branch. This is called generation 4 and the tracing is continued in this manner until the terminal blind-end tubule is reached.

Using this method the following determinations were made in the upper lobe of the right lung. The results were:

| | |
|---|---|
| Embryo I— 11 mm | 3 generations |
| Embryo II— 15 mm | 5 generations |
| Embryo III— 19 mm | 6 generations |
| Embryo IV— 23 mm | 8 generations |
| Embryo V— 35 mm | 10 generations |
| Embryo VI—118 mm | 14 generations |

In all six of these tracheo-bronchial trees it is possible to trace the epithelium as a continuous intact layer from the lining of the trachea outward to the blind end of the terminal tubule that forms the last generation.

The epithelial lining of the tree in Embryos I, II, III, and IV is of a pseudo-stratified columnar type. The lining in the first eight generations of the tree in Embryo V is also of this type. The ninth and tenth generations of this latter tree is lined in most portions by a simple cuboidal epithelium; the remaining portions are like that of the first eight generations. In Embryo V we find the appearance of cartilage plates in the walls of the first three generations of bronchi. The first

eight generations of the tree in Embryo VI are lined by pseudo-stratified columnar epithelium, while the remaining generations (ninth through the fourteenth) are lined by a simple epithelium of a cuboidal type. Cartilage plates are found in the walls of the first six generations of tubules in Embryo VI.

Throughout the extent of the tree, in all of the specimens, the line of the basement membrane of the epithelial cells is distinct. The making of wax reconstructions showed that all of the cross-sections of tubules in an area were parts of the epithelial bronchial system springing from the trachea. The branching tubules in all of these lungs lie in the relatively avascular mesenchyme, which forms the major part of the lung in these stages. There was no formation anywhere in the mesenchyme that even faintly resembled a tubule developing from the mesenchymal tissue.

## SUMMARY

1. The human tracheo-bronchial tree at the 118 mm. stage has a continuous intact lining of epithelium.

2. The tracheo-bronchial tree up to and including the 118 mm. stage appears to grow entirely as a branching of the original fore-gut diverticulum; the mesenchyme has no part in its formation during this developmental period.

3. According to a method of enumeration outlined, the number of generations in the tracheo-bronchial tree at the 11 mm. stage, three, increases to fourteen at the 118 mm. stage.

4. A lobe or a portion of a lobe that has its origin more orad on the primary bronchus is more mature at any period of development than a division that has its origin farther from the bifurcation of the trachea.

5. There is considerable variation in the pattern developed in the human tracheo-bronchial tree.

I am indebted to Miss Thelma Baird, who assisted in the preparation of the serial sections. Miss Baird also prepared the illustrations.

## LITERATURE

1. **Kölliker, A.** Entwicklungsgeschichte des Menschen und der höheren Tiere, II, Aufl., Leipzig, 1879.
2. **Aeby, C.** Der Bronchialbaum der Säugetiere und des Menschen, Leipzig, 1880.
3. **His, W.** Zur Bildungsgeschichte der Lungen beim menschlichen Embryo, Arch. für Anat. und Phys., Anat. Abth., 1887.
4. **Rose, S. B.** Finer Structure of the Lung, etc. Arch. Path., 6:36, 1928.
5. **Policard, A.** Sur la nature du revètement des alvêoles pulmonaires des mammiféres. Bull. d'Histol. 3: 236, 1926.
6. **Terni, T.** La istobiologia del polmone secondo vedute recenti. Minerva Med. 2: 883, 1930.

7. **Narath, A.** Der Bronchialbaum der Säugetiere und des Menschen, Bibliotheca Medica, Abth. A., Anat., Pt. III, Stuttgart, 1901.
8. **Merkel, F.** In volume of Bardeleben's Handb. der Anat. des Menschen. 1902.
9. **Blisnianskaja, G.** Zur Entwicklungsgeschichte der Menschlichen Lungen, Dissertation, Zürich, 1904.
10. **Robinson, A.** Observations on the Earlier Stages in the Development of the Lungs of Rats and Mice. J. Anat. & Phys. 1889.
11. **Flint, J. M.** The Development of the Lungs. Am. J. Anatomy 6: 1, 1907.
12. **Palmer, D. M.** The Right Lung of a Human Foetus of 152 mm. C. R. Length. Ohio Journal of Science, 34: 383, 1934.

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### Applied Entomology

Since the first printing of this book in 1921 many advances have been made in our knowledge of insects and how to control them. In the field of insecticides alone there have been great advances and many of the recommended controls years ago have been modified greatly for the control of the same insect today. The author, in presenting this third edition, has included many of the more recent recommendations for the control of some of our more common insect pests. He has added discussions on the biology and control of a number of insects that have become of economic importance in recent years. The plan of presentation is the same as used in the first and second editions, i. e., that of having economic entomology organized from the systematic viewpoint rather than on the basis of host relationships. No references to literature are given. The scientific names and common names used in the book are those approved to date by the American Association of Economic Entomologists. The acceptance of these names is indeed gratifying.

The book should serve as an excellent text in a general course for beginners in entomology, and is offered at a price more reasonable than most textbooks in entomology. It is well illustrated and printed on a good quality of paper.

R. H. Davidson.

**Applied Entomology,** by H. T. Fernald. 405 pp., 384 figs.; 3rd Edition. New York, McGraw-Hill Book Company, 1936. $3.50.

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### Society and its Biological Future

One of the most brilliant of American scientists has drawn upon his great store of genetic knowledge to attack the problem of man's biological future. For the present stereotyped program of eugenics he has but little sympathy. Beginning with a fine discussion of the biology of man, and of the present and potential future of society, the author presents an ultra-modern view of a truly eugenic program.

To thoroughly change the economic and social pattern of society to a truly co-operative basis; to freely disseminate knowledge of birth control; to legalize abortions as a second line of defense; to make childbirth and the rearing of children easier and less filled with drudgery; to sever love from reproduction, letting each fulfill its own separate function; to produce children, as far as possible, from the eminent men and women of the race by artificial insemination; to socialize our attitude towards our duty to future generations; to understand that the inherent differences between races are insignificant as compared with inherent differences between individuals; to unceasingly search for the ideal genetic compositions, not on the old lines of wealth and class distinctions, but along lines of "comradeliness" and intelligence, that is, highly developed social feeling and highly developed analytical ability; to reach deep into the knowledge of modern biology and shape society and the individuals composing it into an increasingly sublime creation—these are the warp and the woof of which Muller weaves his eugenic program. The book is a challenge to our modern social set-up, and to our ability and willingness to control man's destiny.—L. H. S.

**Out of the Night,** by H. J. Muller. x+127 pp. New York, the Vanguard Press, 1935. $1.50.

# THE TENDENCY TOWARD PROGRESSION OR PERFECTIVE DEVELOPMENT IN PLANT EVOLUTION

## Studies in Determinate Evolution No. IX

JOHN H. SCHAFFNER

After any extensive study of certain fundamental characters or processes in a general taxonomic plant series, a very remarkable tendency becomes evident in that when a new reaction is introduced into the evolutionary movement, it is often much less definite and certain at first than it becomes in forms which plainly belong to a higher general level of organization. This movement toward perfection was evidently recognized long ago by Aristole who must be regarded as a genuine evolutionist. He said that: "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end."

Among the first or perhaps the first of the modern evolutionists to declare an internal force or cause for evolution was the botanist Naegeli. He postulated an internal or innate tendency toward progression and perfect development or a so-called principle of perfection in the evolutionary process, and because of this tendency, according to Naegeli, organisms are constantly varying in such a manner as to rise in the scale of nature.

According to Naegeli, the fact of a progression in the past requires an internal tendency to rise. Darwin's answer to this was that natural selection would also imply progression. But it is evident that if the progression from a lower to a higher, from a less perfect to a more perfect condition were caused by selection, the whole series should not be present but only the more perfected; for the selection of the fittest implies the elimination of the unfit. There can be no selection without elimination. Thus the fact of endless numbers of close, progressive series is a direct refutation of both Lamarkism and Darwinism, since the entire series may be present in the same general environment. A careful study of the taxonomic

*Papers from the Department of Botany, The Ohio State University, No. 352.

system also shows that many of the most definite group characters can have no special adaptative value, can have no special use whatsoever. Whether a flower has a trilocular, bilocular, or unilocular ovulary can be of no special advantage either to the biological relations of the individual or to the individual in relation to its physical environment. Very generally the progressive phylogenetic series does not at all correspond to any ecological zonation. If Lamarkian evolution were in operation, the series should correspond with ecological zonation of habitats, regions, altitudes, latitudes, and other ecological conditions. There plainly is no such correspondence. Furthermore, our recent knowledge of mutation shows that evolution proceeds through individuals and not through the race in general, otherwise the old race would have to disappear in the evolution of the new, and there could not be a series of closely related groups.

Of course, it is evident that if there are orthogenetic series and that they have no general relation to corresponding environmental conditions, the very fact of such orthogenetic series shows that a progressive or perfective principle is involved, and this would not be dependent on the order of appearance or relationships of the units evolved in the series. The fact of the series is immediately of more importance than the order of its production. The progressive movements may be useful or not, or they may even occasionally be decidedly disadvantageous to the individual but may nevertheless continue because associated with compensating conditions. On every hand, one meets structures that the idealist would immediately pronounce perfect as compared with less elaborated types farther down the series. What we wish to consider is the fact that very many evolutionary progressions do become more perfect as one advances in the ascending scale of organism and structure. There is not only improvement, step by step, but the reaction becomes more decided, more definite, more prompt, until failure of expression is practically impossible unless something entirely new is added to the system, which may interfere with the given reaction. This evolutionary improvement of a given reaction must be due to one of two causes, either the structural elements of the protoplasm on which the reaction depends become more perfected in their mechanism or else a greater number of similar units, having the same influence in growth and hereditary expression, are

produced whose combined influence then gives a more vigorous and more dependable action.

In recognizing the fact of a progressive, perfective process and principle in the evolution of potentialities, one is not to postulate or subscribe to an "entelechy" or "elan vital" as an hypothesis to cover our present profound ignorance of the real nature and structure of the protoplast and its evolution. It is sufficient, at present, to study the actual series and their direct implications, which if properly done will keep biologists busy for some time without indulging in speculations for which we have had, up to the present, no adequate accumulation of proper investigations. We know that the evolution of the automobile, for example, is due to the creative activity of the human mind, but we do not on that account endow the automobile with a mind or evolutionary force, to explain the intricacies of its organization. The quest for ultimate causes or an Ultimate Cause does not belong directly to the realm of science but is a philosophical-theological discipline. From the very nature of the case no scientific causal explanation of evolution is possible.

The old unscientific, causal, evolutionary hypotheses, like "chance" or "fortuitous variation," "direct action of the environment," "use and disuse," and "natural selection" must be disregarded and allowed to die a natural death, because they are not only unscientific but are contradicted on every side by the realities of the taxonomic systems; as becomes evident when these are studied in their entirety and in relation to their ecological conditions. Some would-be philosophical scientists are still under the delusion that evolution is primarily concerned with the "origin of species." Speciation has little to do with the real problem of evolution as O. F. Cook pointed out over thirty years ago.

## PROGRESSION IN DEFINITENESS OF DIFFERENTIAL EXPRESSION IN SPOROPHYLL AND FOLIAGE LEAF

In the lower ferns there is no apparent difference between sporophyll and sterile foliage leaf except that the former produces sporangia on its surface and the latter does not. But as one follows out certain evolutionary lines, a very decided dimorphism gradually appears until the two leaves may have very different aspects and characteristics. Thus in *Onoclea sensibilis* L., belonging to the Polypodiaceae, we have rather

an extreme example of dimorphism. This fern shows its advanced character also in having unisexual gametophytes instead of the usual hermaphroditic condition. Now, although the dimorphism is decided, intermediate expressions between sporophylls and foliage leaves are frequently found, and these appear in all gradations from one extreme to the other.

In the Osmundaceae, which represent the lowest family of the Filicales, a rather similar evolutionary movement has taken place. In *Todea barbara* Moore there is little difference between the pinnae which bear sporangia and those which are sterile. But in the extreme species, *Osmunda cinnamomea* L., the dimorphism between foliage leaf and sporophyll is nearly as decided as in Onoclea. Here again intermediate expressions are quite common and it is not difficult to find leaves that are halfway expressions between the two. Apparently a very little disturbance in the ecological-physiological conditions in which the protoplasts are functioning causes a confusion in the hereditary reaction system. Now, as one goes up the phylogenetic scale into the higher plant series one finds not only that there is a still greater dimorphism between foliage leaf and sporophyll but also that intermediate expressions are exceedingly rare or practically nonexistent. It is only when unusual mutative changes have occurred that intermediate expressions may again appear and these, of course, are then not the result of fluctuating expressions. In the highest plants the physiological processes which give rise to the one expression or the other begin in a definite direction and continue thus to the end of the development of the given leaf, whether sporophyll or foliage leaf.

## EVOLUTION OF DEFINITENESS OF DETERMINATION OF THE FLORAL AXIS

The lowest flowers, which represent the first stages of determinateness of the reproductive sporophyll-bearing axis, illustrate the principle of perfective evolution in a very convincing manner. In the lowest living vascular plants, as in the lower lycopods and ferns, the reproductive axis is entirely indeterminate, giving rise indefinitely to successive zones of foliage leaves and sporophylls. From this primitive condition the flower, or determinate sporophyll-bearing shoot, has evolved. The causal factor, therefore, for flower production is determinateness of the reproductive bud. Some potentiality is added

to the protoplast which induces the determinate growth and final death of the bud involved. Now the remarkable thing about this floral evolution is the fact that at first, in the lower levels, the factor or factors of determination act very slowly so that large numbers and usually very variable numbers, are produced before determination of the flower is accomplished. Again, just as in the foliage leaf, the determinate action is frequently inhibited. A small deviation from the normal physiological gradient is enough to induce failure of the determination potentiality and proliferation is the result. In other words, the reproductive bud fails in its determinate process and indeterminate growth continues beyond the reproductive zone just as in plants which have not acquired the reproductive determinate potentiality. The potentiality cannot be depended upon. Proliferation is quite frequent in such low homosporous flowers as *Lycopodium obscurum* L. and *L. complanatum* L. It is also very abundant in some of the lower species of the Equiseta, namely, in *Equisetum fluviatile* L. Frequently also a second cone appears at the end of the proliferated axis, and this second cone may proliferate again. Proliferation of the flowers is frequently seen in some of the lower living conifers, as in both staminate and carpellate cones of *Araucaria angustifolia* (Bert.) Ktz. and the carpellate cones of *Cunninghamia lanceolata* (Lamb.) Hook. The carpellate cones of *Larix kaempferi* (Lamb.) Sarg., *L. decidua* Mill., and *L. laricina* (DuR.) Koch. proliferate occasionally. Proliferation of the flower is also met with occasionally in low types of angiosperms, as in species of Ranunculus, Rosa, and Pyrus. Now in passing along any of the main evolutionary flower series one finds that the determination becomes continually more prompt until at the ends of the series only a few floral parts are produced, in the extreme cases only one, before determination is completed and also that the number of parts is practically without fluctuation. Furthermore, the possibility of proliferation as an ordinary fluctuation is practically eliminated. The determinate reaction gains on the ontogenetic progression, step by step, through the general evolutionary series, in all lines, until in the extreme types the limit is reached when the center of the reproductive bud stops in its growth even before a single incept of any lateral floral organ is in evidence. The evolution of completeness, promptness, and reliability of determination is most remarkable when compared with the variability and

unreliableness of determination in the primitive types of flowers. The failure of prompt determination in the lower types of flowers is also shown in a special way in such groups as Equisetum and Zamia. In the lower species of Equisetum there is a prominent vegetative point at the tip of the cone. In the more advanced series, this point disappears through the more prompt action of the determinate process after the reproductive reactions cease. In *Zamia furfuracea* L. f. also there is a prominent vegetative point on the carpellate cone, associated with a very variable spiral system, while in the higher conifer levels as in *Sequoia washingtoniana* (Winsl.) Sudw. the carpellate cone, which has a 3–5–spiral system but a much more shortened floral axis, has no such point developed. We see then that the evolution of the flower is a vivid demonstration of the perfective principle in evolution, since the reaction advances from a slow movement to a very prompt movement, from a variable action to a mathematically exact reaction, from a frequent failure of action to a dependable action with failure reduced to zero.

### IMPERFECT DETERMINATENESS IN CERTAIN INFLORESCENCE HEADS

In the evolution of the inflorescence to a head, there may be the same lack of prompt determination of the inflorescence axis in the lower species as has been seen in the case of the flower axis. If one studies the evolutionary series in which racemes or panicles are the prevailing types but which have at the end just attained to the condition of having head inflorescences, proliferation is a frequent phenomenon. Thus in the Lamiaceae, the more common condition is to have the flowers axillary, or in racemes, panicles or spikes. In a few genera, however, heads have evolved, as in species of Koellia and Monarda. *Koellia pilosa* (Nutt.) Britt has proliferated heads occasionally and both *Monarda fistulosa* L. and *M. didyma* L. have been seen to proliferate frequently. The Dipsacaceae represent one of the lower families of the Compositales in which great group the inflorescence shows evolution from an elongated head to a very flat disk. Such inflorescences as those of Dipsacus and Scabiosa represent the lower levels while Aster and Leontodon are on the advanced level of disk development. *Scabiosa atropurpurea* L. has frequent proliferation of the head while such a condition is not developed in

the higher Helianthaceae and Cichoriaceae. Again as in the flower, the proliferation of the more primitive heads indicates that the beginning of any important evolutionary movement is usually less stable and less dependable than the more advanced developments in the same phyletic line.

### PEDUNCLES AND PERIANTHS IN EQUISETUM

In the lower vascular plants with primitive flowers, there are no special hereditary potentialities that can come into play in the transition zone between the vegetative axis below and the reproductive axis above, but as we ascend the evolutionary ladder the protoplast acquires a greater and greater accumulation of hereditary potentialities, some of which will be of such a nature as to be thrown into activity on this transition zone. Thus peduncles and perianths soon come into prominence although the lowest species have no such structures. In Equisetum a sterile calyx is thus evolved. In the lowest species of Equisetum the calyx whorl has sporangia in its segments on the upper side while in the higher types, like *E. scirpoides* Mx. and *E. arvense* L., it is completely sterile. But since the evolutionary movement in this respect is not very far advanced, about one out of about every 20 cones in *E. arvense* will have one or more sporangia on the calyx. In a high type of flower, like a Geranium or a lily one would have to hunt a long while before a flower appeared with sporangia on the perianth segments. Only with a special evolution, like a very rapid advance of the time of flower determination in the ontogenetic sequence, would it again be possible to have a confusion of this kind. In Equisetum also the reactions which produce sterile and fertile shoots are not very strongly determined and thus every degree of semisterile cone between a perfect cone and vegetative tip may be easily found in most species. Again in the highest species of Equisetum, *E. arvense*, these intermediate cones are quite rare. The bud usually produces a fertile shoot with a normal cone or a sterile shoot with a vegetative tip. In the higher flowering plants such intermediate developments do not occur unless as the result of extreme mutations or some such special cause. The factors which are responsible for floral shoots or leafy shoots act promptly and decidedly so that no half-way structures are produced unless a decidedly disturbing, new hereditary potentiality has previously been introduced into the system. The lowest species of Equisetum

have no definite peduncle developed below the cone while in the higher a very variable peduncle is present. In *E. arvense* the peduncle may fluctuate from one-fourth inch to more than five inches in length.

### PROGRESSION FROM FIVE–PARTED TO FOUR–PARTED FLOWERS IN DICOTYLS

Although a few of the dicotyl series begin with a trimerous system in the flower, the general rule is a pentamerous type as the basal structure. Frequently then there is a direct mutation to the tetramerous type. In this common progressive change the principle of perfective evolution is also prominently in evidence. A few selected examples are given below. In the Celastraceae, *Celastrus scandens* L. has the usual five sepals, five petals, and five stamens. In the genus Euonymus, the flower has mutated to the four-part condition. Now in *E. obovatus* Nutt., the sepals, petals, and stamens are usually five each; but occasionally a four-parted flower is produced beside the five-parted ones. A mutation has been accomplished in the species but this new factor acts only occasionally in a special physiological condition which arises in the same cell complex as the condition which leads to five-parted flowers. In *E. atropurpureus* Jacq., the flower is usually four-parted, but sometimes five-parted flowers are produced along with the four-parted in the same cluster. In *E. europaeus* L. and *E. alata* Regel, the flowers are four-parted and only rarely is a five-parted flower developed on the plant. Finally in a related genus, in *Pachystima canbyi* Gr., the flower is regularly four-parted with four sepals, four petals, and four stamens. The potentialities responsible for the four-parted reaction have become perfected so that there is no failure.

*Ruta graveolens* L. has four-parted flowers, but usually the central flower of each main branch of the flower cluster has a five-parted flower. The mutation does not work in the central gradient. The Tubiflorae are characteristically a group with pentamerous flowers and this is true for part of the Gentianales, but in the Oleaceae, the flower has mutated to a four-parted perianth. Now in the common lilac, *Syringa vulgaris* L., although the flowers are mostly of this type, very many of the panicles show flowers with a five-parted perianth, usually at the end of the panicle or toward the center of some of its branches. In mutating to the four-parted condition, the plant

did not loose the potentialities which produce five-partedness. Occasionally a three-parted flower is produced. The factors which change the reaction of the flower bud from a five-parted to a four-parted condition bring about a further reduction, which indicates that a further mutation might occur which would give rise to a three-parted lilac. In the golden-bell (Forsythia), five-parted flowers are less common than in the lilac.

The Crassulaceae also show a fundamentally pentamerous condition of the flower, but with a strong tendency to mutate to a tetramerous condition. Many of the genera have flowers of both types. Some of the genera have five-parted flowers regularly. In *Sedum triphyllum* (Haw.) S. F. Gray and *S. telephioides* Mx., the flower is five-parted, while in *S. acre* L. and especially in *S. ternatum* Mx. the central flower of the cyme is commonly five-parted while those on its branches are four-parted. Thus again, in Sedum we see a mutation to a four-parted condition but the factors involved are not in such a state as to completely prevent the more fundamental pentamerous potentiality from being expressed in certain parts of the inflorescence.

## THE PERFECTIVE TENDENCY IN THE EVOLUTION OF ZYGOMORPHY

The lower types of flowers, whether spiral or cyclic, are all radially symmetrical. On the higher levels in most lines of monocotyls and dicotyls, zygomorphy appears and sometimes becomes very extreme. The most fundamental movement in the evolution of zygomorphy is the more prompt determination of one side of the determinate flower bud than the other. Along with this progressive movement, usually, various factors of shape, color, texture, ornamentation, etc., are evolved. As stated, zygomorphy is usually not encountered until the series has advanced to a considerable degree of complexity. However, occasionally a distinct zygomorphy is found even in the primitive spiral stage. Thus in *Pinus radiata* D. Don., *P. muricata* D. Don., *P. attenuata* Lem., *P. sabiniana* Dougl. and other species a decided zygomorphy is produced by the difference in character of the ovuliferous scales on the inner and outer sides. Although the pine cone is a low type of flower it, nevertheless, does have a high degree of complexity of reactions when compared with such simple systems as are

presented by the cones of Lycopodium, Zamia, or Araucaria. In the dicotyls, a prominent development of zygomorphy is known in some genera of Ranunculaceae which represent a very low condition otherwise. The flowers of Aconitum and Delphinium have not advanced beyond the apocarpous stage, yet zygomorphy is pronounced in both calyx and corolla.

The evolution of zygomorphy, like other fundamental movements, shows a decidedly progressive and perfective sequence in many series. Thus a series of genera or species may show a progressive reduction of stamens from 6 to 5 to 3, and then to 2 or to 1; or from 5 to 4 to 2, to 2 halves. In the Scitaminales, Ravenala has 6 stamens, which is the fundamental number for all the Liliiflorae whether hypogynous or epigynous. It has a slight zygomorphy but not enough to eliminate any of the stamens. In its near relative, the banana, *Musa sapientum* L., one stamen is missing in both staminate and carpellate flowers. There is simply an empty space where the stamen should appear on the zygomorphic plane. Now on almost any bunch of banana flowers one can occasionally find this sixth stamen developed in one or more flowers. It may be a perfect stamen or a vestige of any degree of expression. The banana flower has only taken the first step of sufficient size to eliminate one stamen and the condition is not perfected in relation to the general reaction system, and so frequently the original condition is produced which gives six stamens. A little disturbance in physiological condition brings back the original structural type. In the higher Scitaminales there are but five stamens or sometimes only three, all except one of which are changed to showy staminodes. In the two highest families, Cannaceae and Marantaceae, there is an unsymmetrical potentiality introduced which also affects the remaining fertile stamen which is then reduced to a half fertile stamen. The whole flower is now bilaterally unsymmetrical but still shows its complete evolutionary history in its make-up—(1) spiral symmetry, (2) cyclic symmetry, (3) zygomorphic symmetry, (4) inequilateral condition. So far as the andrecium is concerned the evolutionary sequence has attained to its definite determinate limit at the one-half stamen condition. In the Orchidales zygomorphy also brings about a reduction of the stamens from six to one, the very vast majority of orchids, 10,000 or more, having this one stamen in the same position on the zygomorphic plane in relation to the other

parts. Those who still think that there is any fortuity in the fundamental processes of evolution should study the structural relations of this one stamen in the Orchidaceae.

In the Scrophulariaceae there are various zygomorphic reduction series, the stamens running from five to four to two. In the Bignoniaceae, Bignonia, Anisostichus, and Tecoma have four anther-bearing, didynamous stamens with a vestige of the fifth. Paulownia shows the same condition. But in Catalpa the anther-bearing stamens are reduced to two, through the advancement of the zygomorphic evolution, with three prominent vestiges. Now just as in the banana, the two lateral, reduced stamens, especially in *Catalpa speciosa* Ward., sometimes develop normally, giving flowers with four stamens. Occasionally all five stamens develop normally. These four- or five-stamened flowers appear in the panicles along with the characteristic two-stamened flowers. It is not a matter of segregation of old heredity from new heredity but rather the expression of an old suppressed heredity over a more recently acquired heredity potentiality through some local change in physiological activity.

In the Lamiales, the lower types again show the fundamental number of five functional stamens. Then in the Lamiaceae, Isanthus has four didynamous stamens and this is the usual condition of most of the intermediate genera, while Monarda and Blephilia have but two. Finally in Salvia the zygomorphic advancement is extreme and not only gives a zygomorphic calyx and an extremely zygomorphic corolla, but the two remaining stamens also are decidedly affected by the zygomorphy and show a progressive advance so that in the higher species each stamen has but a half anther, the other half being transformed into a peculiar lever-handle. The zygomorphic evolution has advanced to the last possible degree of perfection in so far as it can affect the stamens.

The general trend toward a perfective advancement in the evolutionary process is also prominently shown in the zygomorphic conditions of the closely related families, Cistaceae and Violaceae. The Hypericaceae represent a more primitive, actinomorphic group belonging to the same general series. In Crocanthemum, the flowers have an actinomorphic aspect, but close examination shows that the two outer lateral sepals are smaller and narrower, or sometimes wanting. In Cubelium the flowers are only moderately zygomorphic, the petals being

nearly equal. The lower one is, however, somewhat gibbous, but the andrecium and calyx show little or no zygomorphy. In Viola the zygomorphy becomes successively more and more extreme until in such species as our common blue violet, *Viola papilionacea* Pursh, the petaliferous flowers are extremely zygomorphic, having three distinct types of petals, two very distinct types of stamens and even a somewhat zygomorphic calyx and gynecium. Those who have thought that such a series was produced by natural selection because of the highly specialized character of the flower, with its nectar spur, adapted for insect pollination, should certainly be shocked to find that these highly perfected, zygomorphic, insect-attractive flowers are either completely sterile or produce very few seeds, while the later-developed, cleistogamous flowers, which have no corolla whatever and are entirely self-pollinated, are abundantly fertile and produce great quantities of perfect seed. Such cleistogamy is found in many genera of both anemophilous and entomophilous plants. It is plain that the perfection of the zygomorphy and the showyness of the petaliferous flower were evolved neither through any selective action of visiting insects or other environmental conditions nor through any direct response to an unusual physical environment. One might remark in passing, that to the crude pseudo-science of the past century, such a zygomorphic, showy corolla as is present in the higher types of violets was conclusively an "attractive adaptation to fertilization" and the irregularity of the zygomorphic shape was to provide a suitable landing place for the visiting insects. The evolution of zygomorphy in the Violaceae is accompanied by another interesting development, namely, the elongation of the flower peduncle. In *Cubelium concolor* (Forst.) Raf. the peduncle is ¼–¾ inches long; in *Viola canadensis* L. 1–2 in.; in *V. eriocarpa* Schw. 1½–3 in.; in *V. conspersa* Reich. 2–4 in. These species have aerial leafy shoots while the remaining ones mentioned below have geophilous stems. *V. blanda* has peduncles 2½–5 in. long; *V. cucullata* Ait. 4–7 in.; *V. papilionacea* Prush 4–8 in.

Since there is no advantage to the plant in thrusting its showy flowers up, to the convenience of the pilfering insects, the "adaptation" must be for some other important "use." And in the spring see how readily the children can and do gather these pretty flowers and how "perfectly adapted" they are for making great bouquets! "Adaptation" is a

wonderful thing! In this connection, the "adaptation" to insect pollination of the common milkweeds may be considered. In the Apocynaceae the pollen is glandular, although the pollen-grains are simple, but in the next higher family, Asclepiadaceae, more definite pollinia or granular masses are developed which in Asclepias and other genera become marvelous structures that can only be removed and carried about through the aid of insects. Two flattened, pear-shaped, waxy pollen-masses from two adjacent anthers form a pair suspended on curved threads from a peculiar connective which has a slit in which the proboscis or foot of the unlucky insect is caught and from which it cannot escape without either leaving its leg behind or carrying the whole apparatus with the two pollen-masses away. A more perfect or ingeneous devise could hardly be conceived. Yet this perfected mechanism is so inefficient in inducing pollination of the milkweed flower, that, after a careful statistical study of our common *Asclepias syriaca* L., over a wide extent of territory, it was found that less than one flower in 100, under all ordinary environmental conditions, ever becomes pollinated. The milkweed "adaptation" is about as inefficient a method of pollination as could be devised.

## VARIOUS OTHER EXAMPLES OF THE OPERATION OF THE PROGRESSIVE, PERFECTIVE PRINCIPLE

The genus Thalictrum belongs to a family whose flowers are mostly bisporangiate. In Thalictrum, however, there is a gradation series of species running from the perfect condition to a rather decidedly diecious state. *Thalictrum clavatum* D C. has bisporangiate flowers, *T. polygamum* Muhl. usually bears both bisporangiate and monosporangiate flowers. *T. dasycarpum* Fisch. & Lall. is diecious but frequently develops individuals with both kinds of monosporangiate and also bisporangiate flowers, and the sex is easily partially or completely reversed from time to time through ecological control. *T. dioicum* L. is decidedly diecious and individuals with some perfect or completely reversed flowers are comparatively rare. It is also more extreme in its general morphological characters than the other species mentioned. Under experimental control it is also more constant in sex than the other species mentioned above. All species of Thalictrum fall into this series in respect to their sexual conditions. A somewhat similar series is presented by the genus Fraxinus. The genus Acer shows a condition

somewhat similar to Thalictrum. The ancestral type of Acer had bisporangiate flowers as is plainly indicated by the prominent vestigial sporophylls of the opposite sex condition in the flowers of the more primitive species. *Acer plantanoides* L. has prominent petals, nectar glands, large vestiges of the opposite sporophylls, and frequently reverses the sex in either direction, sometimes involving rather large branches. *A. rubrum* L. and *A. saccharinum* L. have small vestiges of the opposite sporophylls but still show frequent sex-reversals, although the phenomenon does not appear to be so common as in *A. plantanoides*. Finally *A. negundo* L., an extreme species in many characters, shows no vestiges of the opposite sporophylls in the flower and also shows sex-reversal very rarely, although such reversal has been reported. There is thus a progressive degree of perfection and constancy in the evolution of the secondary sexual states. Similar conditions have been found in quite a number of other diverse genera, both by observation and by direct experiment. In the genus Acer, there is evident another interesting condition. Acer belongs to a series of groups that are prevailingly tricarpellate. But Acer itself has advanced in the same direction as nearly all advanced dicotyls and has become bicarpellate. Now in various species of Acer, tricarpellate ovularies and fruits frequently appear and sometimes even four perfect carpels may be present. The evolutionary change from three carpels to two carpels is again such that the reaction is not always perfect and a reversion to the more primitive condition takes place, not because of a mutative loss of the factor but merely because of a failure to react properly in the given physiological condition of the cells involved. Thus the old reaction, which was never lost, comes into play again. Similar reversions are seen in many other plants. *Juglans regia* L. frequently has tricarpellate gynecia.

Another good example of the imperfect development of an important potentiality in its first phylogenetic stages is the genus Arisaema. The lowest Aroids have bisporangiate flowers while the remaining ones are monecious with the exception of Arisaema, which contains both monecious and diecious species. In some of the monecious species, as in *A. dracontium* (L.) Schott., the plant is easily reversed from moneciousness to a staminate condition or from staminate to monecious. With greater difficulty the monecious condition can be caused to

approach a nearly complete carpellate condition. *A. triphyllum* (L.) Torr. is more decidedly diecious and is perfectly balanced so that the sex-reversal can be easily induced in either direction from the one sexual state to the other or to moneciousness. It is said that some species of Arisaema are much more stable in their sexual states than is *A. triphyllum.*

The perfection principle and orthogenetic series are again illustrated by the splitting of the husk of the fruit in the genus Hicoria. In *Juglans regia* L. the husk separates from the nut or pit as in a hickory but does not split. In *Hicoria cordiformis* (Wang.) Britt. the husk is tardily four-valved. In *H. microcarpa* (Nutt.) Britt. the husk splits tardily and incompletely to the base. In *H. villosa* (Sarg.) Ashe. the husk splits partly to the base. In *H. ovata* (Mill.) Britt. the husk is thick and soon splits into four valves to the base. In *H. carolinae-septemtrionalis* Ashe. the husk soon splits completely and falls readily into four valves or pieces.

The Nymphaeales as well as certain other groups show a progressive, perfective series in the evolution of staminodes. In Brassenia and Cabomba, which have the lowest apocarpous, hypogynous type of flower, there is no sign of any disturbance between the perianth and andrecium. In *Nymphaea advena* Sol., with a syncarpous, hypogynous flower, there is a slight development of staminodes at the base of the andrecium, usually confined to the outermost members. These stamens are slightly enlarged, flattened structures which still show vestigial microsporangia and have only a slight degree of petal characteristics. In *Castalia odorata* (Dry.) W. & W., which has a syncarpous flower in the first stage of epigyny, there is a prominent zone of staminodes, ranging from typical petals at the outer margin to typical stamens at the inner margin, between the true corolla and the normal stamens. Finally in *Victoria regia* Lindl., which belongs to the epigynous Nymphaeaceae with epigynous hypanthium, the development of petal-like staminodes is more extreme even than in Castalia.

In the Apocynaceae and Asclepiadaceae, the bicarpellate ovulary undergoes a characteristic splitting which sometimes includes even part of the style. These separated carpels develop into two follicles. The splitting is a secondary character evolved in the syncarpous condition. In some Apocynaceae the carpels are not thus split apart but continue in the same general condition as all the lower Tubiflorae.

Apocynum is a genus in which definite splitting occurs. Now in studying the development of the fruit of species of this genus it was found that *A. cannabinum* L. sometimes develops fruit to maturity without any splitting taking place. This again illustrates the principle that those groups or species which represent the first steps of an evolutionary series do not have the potentiality in as definite and perfect a state as those more advanced in the series. In Asclepias the splitting apparently occurs regularly, although no extensive observations have been undertaken to determine this definitely.

In both Monocotyls and Dicotyls, the co-ordinating reactions in the stem bud, which determine the position of the leaves, frequently indicate a definite evolutionary movement from a several-spiral condition to a two-ranked condition or unaspiral as the determinate culmination type. The Monocotyl lines nearly all end in a unaspiral. The three closely related genera of Fagaceae, Quercus, Castanea, and Fagus, show a perfective movement toward a definite, two-ranked reaction potentiality. *Quercus muhlenbergii* Engelm. and other species do not have a two ranked leaf arrangement but a typical 2–3 spiral system. The winter bud scales also indicate a primitive condition, having a 2–3 spiral system with 5 spiral radii in evidence. In *Castanea dentata* (Marsh.) Borkh. some of the twigs have two-ranked leaves and some have a more primitive spiral system like the oak. The two kinds of branches appear on the same tree. The potentiality for two-ranked has been acquired but often fails to come into play. In *Fagus grandifolia* Ehrh. the leaf arrangement is regularly and perfectly two-ranked under all ordinary conditions. In this series the movement is from no two-ranked potentiality, to a potentiality for the two-ranked expression which is decidedly unreliable and indefinite, to a two-ranked potentiality which is of such a nature that the hereditary expression is perfect in all ordinary physiological-ecological conditions. The characters of the fruit cups and involucres and of the staminate catkins also determine the progressive phylogenetic series as (1) Quercus, (2) Castanea, (3) Fagus independently of the orthogenetic series shown by the leaf arrangement.

## THE PERFECTION PRINCIPLE ILLUSTRATED BY THE EVOLUTION OF AN ISOBILATERAL SYSTEM

The typical isobilateral flower is a rare type. It is ideally developed in the Fumariaceae. This type of symmetry is

gradually evolved as one passes from the lower Papaveraceae into the middle of the Fumariaceae. It is also developed in the Brassicaceae and Capparidaceae but not to such an extreme condition. An isobilateral flower or organ may be defined as one that can be cut into equal halves by two planes, intersecting at right angles, the halves of the one plane being unlike those of the other. In typical cases there is a reduction in the one plane as compared with the other. Often, both the number of parts and the forms and peculiarities of the non-corresponding halves are different.

In the lowest Papaveraceae, the entire flower shows nothing but the primitive spiral and cyclic, radial symmetry. There is no evidence of bilaterality of any kind. *Romneya coulteri* Harv., the matilija poppy of southern California, is described as having constantly 3 sepals, 3+3 petals, many stamens, and numerous united carpels. I have not had the opportunity to study this species. *Platystemon californicum* Benth. has a similar structure with 3 sepals, 3+3 petals, 42, more or less, stamens, and 6–18 carpels.

In *Argemone intermedia* Sweet, White Prickly-poppy (Figs. 1, 2), a common species of the western prairie and plains, the majority of flowers on a plant usually have the primitive trimerous perianth, 3 sepals, and 3+3 petals, with a very variable number of stamens, 184–336, and 2–6 carpels. Fig. 1 represents a typical actinomorphic flower, while Fig. 2 represents a rather reduced isobilateral type. These two types of flowers occur on the same plant but the radially symmetrical ones are much more abundant than the isobilateral ones. The species represents a plant that has taken the first step toward the isobilateral condition and the new character is very unreliable in expression. It is not a matter of hereditary segregation but one of hereditary expression, and the old trimerous heredity in the great majority of flower buds comes to activity rather than the new. The principle of imperfection is strikingly in evidence.

The commonly cultivated oriental poppy, *Papaver orientale* L. (Figs. 3, 4) is somewhat farther along the road toward isobilaterality. Sometimes the flowers with actinomorphic perianths and with isobilateral perianths are produced about equally, but at other times either the isobilateral or the actinomorphic type is the more abundant. As in *Argemone intermedia* both types of flowers are commonly produced on the same

plant. In the general advancement of determinateness the oriental poppy is still in the more primitive condition both in respect to stamens, 390–450 ±, and carpels, 10–15 ±.

The more typical poppies have an isobilateral perianth with 2 sepals and 2+2 petals quite regularly. *Papaver dubium* L. (Fig. 5) is of this type, with an isobilateral perianth, 232 ± stamens, and 7 ± carpels (6–10). In general the flower is decidedly reduced when compared with *P. orientale*.

In *Stylophorum diphyllum* (Mx.) Nutt. (Fig. 6) the flower again shows a decided reduction over that of *Papaver dubium*, having 2 sepals, 2+2 petals, 72 ± stamens and only 4 carpels, or sometimes these are reduced to 3 or 2. *Chelidonium majus* L. (Fig. 7) is approaching quite near to the perfect isobilateral type with 2 sepals, 2+2 petals, 2 carpels and only 16 ± stamens (14–24).

Passing over to the Fumariaceae, we find the isobilateral symmetry perfectly developed. In the Dutchman's-breeches, *Bicucula cucularia* (L.) Millsp., the flower (Fig. 8) has 2 sepals, 2+2 petals, 2+4 stamens and 2 carpels. The isobilateral movement has finally attained mathematical perfection. The two outer petals are spurred while the two inner ones have no spurs. A somewhat similar condition is developed in some Brassicaceae, but to a decidedly less extent, as in *Cheiranthus cheiri* L., *Ricotia lunaria* DC., and *Lunaria annua* L. While the flower has progressed to ideal isobilaterality, the fundamental progression of more prompt determination of the floral axis in relation to the beginning of the reproductive reactions has continued, and in the Bicucula type the upper 4 stamens are reduced as compared with the 2 lower ones, having only 2 microsporangia while the lower ones have the usual 4 microsporangia. This is a characteristic example of the way characters evolve as the result of some fundamental orthogenetic movement and not through natural selection in a life and death struggle nor as a response to use and disuse. It would certainly require a marvelously credulous mind to see any advantage in having the 2 outer stamens developed with 4 sporangia and the 4 inner stamens with only 2 sporangia each. This peculiarity is present in other genera of the family. Great numbers of similar situations are in evidence when one makes a proper taxonomic analysis of the various plant groups. Now the general orthogenetic movement of the time of floral determination could be carried still further and there are genera with

more reduced numbers. In the Brassicaceae the isobilateral flower is sometimes reduced to the formula—sepals 4, petals 0, stamens 2, carpels 2, as in *Lepidium ruderale* L.

In the Fumariaceae, a new evolutionary trend is introduced in some species, namely, a zygomorphic potentiality which is imposed upon the isobilateral condition. A typical example is presented by *Capnoides aureum* (Willd.) Ktz. (Fig. 9). Structurally the flower is isobilateral in even a greater degree than in Bicucula, having the 6 stamens united by their filaments into 2 groups. The outer pair of petals show a strong zygomorphy in that one is spurred and the other is not. There is also a nectar gland at the base of the spurred petal and none at the base of the opposite petal. This flower series, therefore, shows the general evolutionary series of the poppy-fumatory group to have progressed from a slow, variable determination to a prompt, definite determination; from spiral to cyclic; from actinomorphic to isobilateral; and finally from the isobilateral to the zygomorphic condition. Usually the advanced movement is from actinomorphy directly to zygomorphy; and then rarely an unsymmetrical condition of form and general expression may be added on top of the zygomorphic condition.

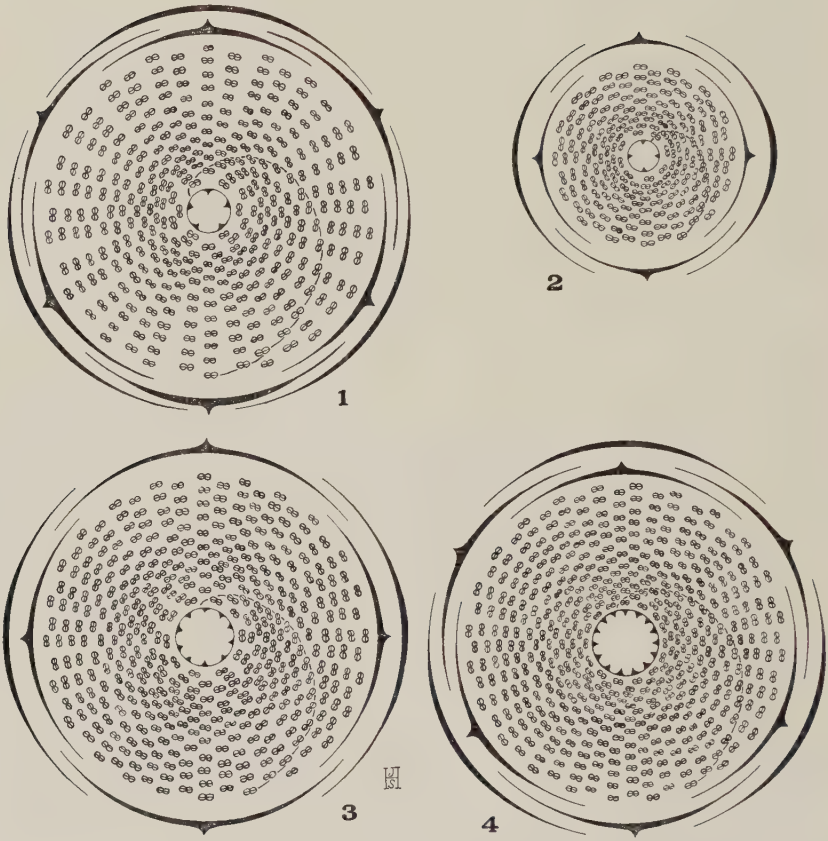
To some, the term perfective, or perfection, more commonly conveys the idea of an immediate ideal goal or attainment; and from a utilitarian standpoint of evolution such might be the inference. But aside from a philosophical attitude one may have in asserting that there is in the organic world a system and principle which does bring about an orderly cosmos and a highly successful balance of nature, this idea should not be entertained in relation to the scientific study of the perfective development of characters and properties of organisms. As intimated in at least one example of perfective evolution given above, the result may be a decided disadvantage to the individual in relation to its environment, or the mechanism may be highly perfected and still be of no use whatever to its possessor. In this world, a thief may attain perfection in his calling as well as a saint. However, in its broadest aspects, the general course of evolution is perfective in the ethical and altruistic sense, at least to all people so philosophically inclined as to be able to view the system as a whole.

## SUMMARY STATEMENT

There is a manifest tendency toward progression and perfective development in the evolution of many fundamental plant series. This progression in perfection of structures and reactions is not to be ascribed to any selective principle nor to any direct reaction to a series of changing environments, either in time or space, but to some internal cause dependent on the nature of the protoplasm involved.

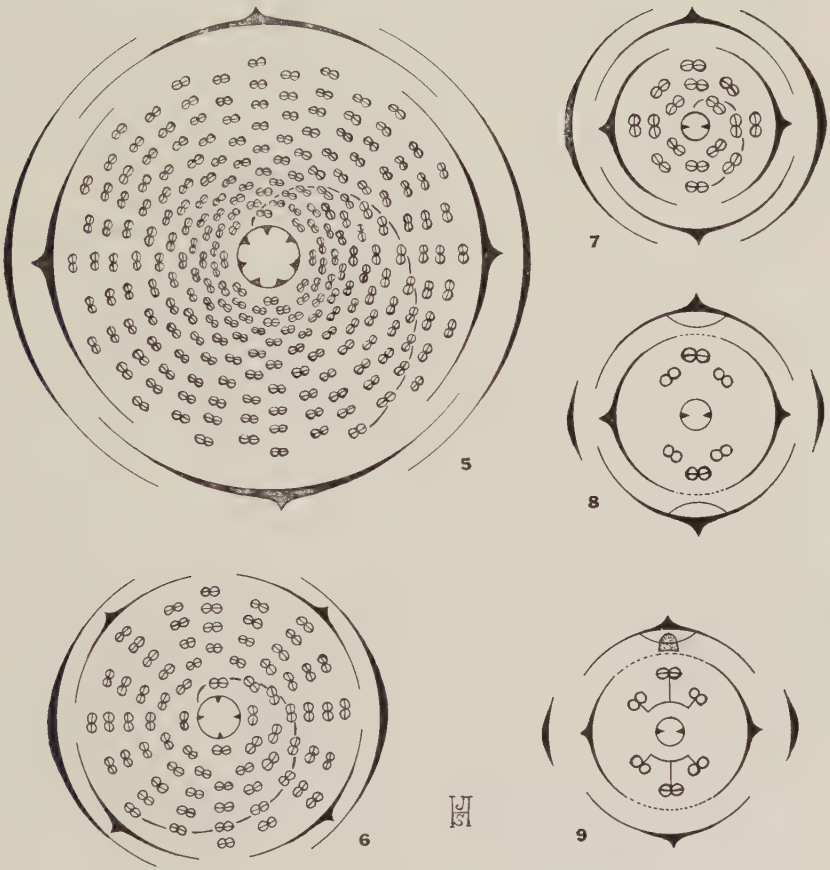
Among the more important examples discussed, in the present paper, of evolutionary series showing progressive, more dependable, and more prompt reaction in passing from the lower to the higher members are the following: Progression in the definiteness of differentiation expression in sporophyll and foliage leaf. Evolution of definiteness and promptness of determination of the floral axis. The more definite determination of the inflorescence axis in the higher as compared with the more primitive types of inflorescence heads. The instability of the reaction on the lower evolutionary levels in passing from a five-parted to a four-parted flower in various dicotyls. The decided perfective tendency in the progressive evolution of zygomorphy. The progressive and perfective series shown in the evolution of the isobilateral type of flower from the more primitive actinomorphic type in the Papaveraceae-Fumariaceae group.

The facts presented, together with a large array of similar phenomena which might be adduced, indicate decidedly the presence of an internal perfective principle operative in the evolution of organisms and that evolution in its fundamental aspects is intrinsic, orthogenetic, progressive, perfective and determinative.




Diagrams of floral structures in the isobilateral series in Papaveraceae and Fumariaceae.

1. *Argemone intermedia* Sweet. Sepals 3, petals 3+3, stamens 336, carpels 5. Actinomorphic.
2. *Argemone intermedia* Sweet. Sepals 2, petals 2+2, stamens 184, carpels 4. Isobilateral.
3. *Papaver orientale* L. Sepals 2, petals 2+2, stamens 390, carpels 10. Isobilateral.
4. *Papaver orientale* L. Sepals 3, petals 3+3, stamens 450, carpels 15. Actinomorphic.




Diagrams of floral structures in the isobilateral series in Papaveraceae and Fumariaceae.

5. *Papaver dubium* L. Sepals 2, petals 2+2, stamens 232, carpels 7. Isobilateral.
6. *Stylophorum diphyllum* (Mx.) Nutt. Sepals 2, petals 4, stamens 72, carpels 4. Isobilateral.
7. *Chelidonium majus* L. Sepals 2, petals 2+2, stamens 16, carpels 2. Isobilateral.
8. *Bicucula cucularia* (L.) Millsp. Sepals 2, petals 2+2, stamens 2+4, carpels 2. Perfectly isobilateral.
9. *Capnoides aureum* (Willd.) Ktz. Sepals 2, petals 2+2, stamens 2+4, carpels 2. Isobilateral-zygomorphic type.

# EARTHWORMS OF MISSOURI

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Earthworms are among the most common of our animal forms but they have received very little attention from taxonomists and the fauna of this country is not very well known. Because the natural history of the earthworm is but little known to the average reader, it is commonly regarded as a useless and uninteresting creature, which may occasionally serve for bait. However, earthworms play a very important part in the teaching of zoology and in research, they are used quite extensively for studies of reactions, embryology, histology and regeneration; and to the ecologist they present some interesting problems in distribution.

Our knowledge of the group has chiefly been developed by Michaelsen, Stephensen, Eisen, Vaillant, Vejdovsky, Benham and Beddard, who are responsible for the literature on the Lumbricidae. The literature on North American earthworms is decidedly meager. Several foreign zoologists have worked on American material, but naturally they have been greatly handicapped in securing sufficient collections. Professor Frank Smith has given them more attention than any other American worker. Among other things, he has published (1928) a very complete list of the earthworm fauna of Illinois. The author (1928) published a paper on the earthworms of Ohio with a study of their distribution in relation to the hydrogen-ion concentration, moisture, and organic content of the soil. To my knowledge these are the only regional papers published on North American earthworms. I have not been able to discover a single record for any species of earthworms in Missouri. The present paper is based on my personal collections which have extended into 25 counties of the state during a period of four years. In addition collections were made by various friends and students.

## DEFINITION OF TERMS USED IN IDENTIFICATION

Smith (1917) has published a definite system of terms and symbols and his statement with some modification will be adopted for use in this paper.

The limits of somites externally are indicated by the intersegmental grooves between the segments, while internally the septa or partitions serve this purpose. The somites are numbered from the anterior end, not counting the prostomium, which is not a segment. Each somite is designated by arabic numerals. Should the first intersegmental groove be obscure, one can distinguish the second somite, since it is the first to bear setae. The intersegmental grooves for any two adjacent somites are represented by a formulae; 5/6 indicates the groove between segments 5 and 6.

In the Lumbricidae there are eight setae to a somite, and these are usually arranged in pairs, two pairs on each side. They may be closely or widely paired or separate. The setae on either side are indicated by the use of letters, a, b, c, and d. The ventral-most setae is designated by a, the next by b, and the next by c, and the dorsal-most by the letter d. Should the distance between a and b and between c and d be less than one-third of the distance between b and c, the setae are said to be closely paired.

If the prostomium divides the peristomium completely and the longitudinal grooves which form its lateral boundaries extend clear to the intersegmental groove 1/2, the prostomium is said to be *tanylobic*. Should the prostomium and its lateral grooves extend only part of the way across the peristomium and fails to reach the groove 1/2, it is said to be *epilobic*. When the prostomium and the peristomium are entirely fused or coalesced, it is said to be *zygolobic* (Spargonophilus).

On some of the somites of the clitellum along the ventral edges, there are some glandular ridges termed tubercula pubertatis. They may vary as to their position in the clitellar region, and may in some cases be absent. The spermathecae are pouches which may open to the exterior and receive the sperm cells from the individual. They vary in position, and in some species are totally absent. The oviducal pores are on somite 14 in the Lumbricidae. The spermiducal pores are usually on somite 15, but in some of the Lumbricidae they are present on somite 13.

## FAMILY LUMBRICIDAE

This family has eight setae per somite. The anterior border of the clitellum is posterior to the spermiducal pores which in most cases are on somite 15, but in few cases are from

KEY TO THE EARTHWORMS OF MISSOURI

| Clitellum | Tubercula pubertatis | Prostate pores | Spermaducal pores | Spermathecal pores | Sperm sacs | Setae | Number of Somites | Length (cm) | Color antero-dorsal | Name |
|---|---|---|---|---|---|---|---|---|---|---|
| 13–18 sad. | | 18, 20 | 19 | 7/8, 8/9 | 9, 12 | Wide | 135–160 | 20–27 | Brown | *Diplocardia riparia* |
| 13–18 sad. | | 18, 20 | 19 | 6/7, 7/8, 8/9 | 9, 12 | Wide | 125–160 | 18–30 | Pale | *Diplocardia communis* |
| 13–18 cing. | | 18, 20 | 19 | 6/7, 7/8, 8/9 | 9, 12 | Wide | 90–120 | 5–10 | Pale | *Diplocardia singularis* |
| 22, 23–36, 27 | 23–25, 26 | | 13 | 9/10, 10/11 dorsal | 9, 11, 12 | Close | 80–100 | 4–6 | Brown | *Helodrilus tetraedrus* f. *typica* |
| 22, 23–27 | 23–25, 26 | | 15 | 9/10, 10/11 dorsal | 9, 11, 12 | Close | 80–100 | 4–6 | Brown | *H. tetradrus* f. *hercynius* |
| 22–29 | None | | 15 | None | 11, 12 | Close | 100–110 | 4–7 | Brown-red | *H. gieseleri* var. *hempeli* |
| 25, 26–32 | 29–31 | | 15 | 9/10, 10/11 | 9–12 | Close | 130–150 | 4–8 | Pale red | *H. roseus* |
| 24, 25 or 26–32 | 28–30, 31 | | 15 | 9/10, 10/11 | 9–12 | Close | 75–125 | 5–15 | Brown & Buff (bands) | *H. foetidus* |
| 26–31 | 28–30 | | 15 | 9/10, 10/11 | 9, 11, 12 | Wide | 80–125 | 5–8 | Red | *H. subrubicundus* |
| 26–31 | 29, 30 (indistinct) | | 15 | None | 11, 12 | Wide | 90–110 | 4–8 | Red | *H. tenuis* |
| 27–34, 35 | 31, 33 | | 15 | 9/10, 10/11 | 9–12 | Close | 100–250 | 5–20 | Rose-red | *H. caliginosus* f. *typica* |
| 27–34. 35 | 31–33 | | 15 | 9/10, 10/11 | 9–12 | Close | 100–250 | 5–20 | Rose-red | *H. f. trapezoides* |
| 27–37 | None | | 15 | None | 11, 12 | Close | 110–140 | 10–12 | Chestnut-brown (purplish) | *H. zeteki* |
| 27–32 | 28–31 | | 15 | 9/10, 10/11 | 9, 11, 12 | Close | 90–145 | 7–13 | Reddish-brown (violet) | *Lumbricus rubellus* |
| 29–37 | 31, 33, 35 | | 15 | 8/9, 10/11 | 9–12 | Close | 80–125 | 5–7 | Greenish | *H. chloroticus* |
| 30–35 | 31–34 | | 15 | 9/10, 10/11 | 9–12 | Wide | 100–170 | 5–16 | Pale-pink | *Octolasium lacteum* |
| 31, 32–37 | 33–36 | | 15 | 9/10, 10/11 | 9, 11, 12 | Close | 125–175 | 15–25 | Brown-violet | *Lumbricus terrestris* |

one to three somites further anterior. The calciferous gland is situated in the region of the gonads. A gizzard is present at the anterior end of the intestine. There are no typical prostate glands extending free into the coelomic cavity. The spermaries and spermiducal funnels are in somite 10 and 11. The ovaries are in 13. The oviducal pores are in 14.

## HISTORICAL

The genus *Lumbricus* and the old *genus Allolobophora* are practically the only important terrestrial genera of the Oligochaetous worms prevalent in North America and Europe. Michaelsen (1910), in a discussion and revision of various genera of Lumbricidae, reduced the genera to three. They are *Helodrilus*, *Lumbricus*, and *Octlasium*, and are widely distributed in all parts of the world except in the tropics, and are especially abundant in the United States. Smith (1928) listed 18 species in this family for the state of Illinois. The author (1928, 1933) listed 19 species for the state of Ohio.

### Genus **Lumbricus** Linneaus (1758) Amended Eisen (1874)

Prostomium completely divides peristomium and longitudinal grooves which form its lateral boundaries extend to inter-segmental groove 1/2 (tanylobic). Spermaries and spermiducal funnels inclosed in sperm vesicles. Sperm sacs are in 9, 11, and 12. Setae closely paired posterior to clitellum.

### **Lumbricus terrestris** Linnaeus (1758)

Length 15 to 25 cm. Somites 125 to 175. Color, anterior dorsal surface, brownish blue, reflecting prominent greenish-violet color. Clitellum covers somites 32 to 37, and may begin on somite 31. Tubercula pubertatis on 33 to 36. Prostomium, tanylobic. Setae closely paired. First dorsal pore on 7/8. Oviducal pore on 14, slightly dorsal to b. Spermiducal pores on 15, between b and c. Spermathecal pores on 9/10 and 10/11, in line with cd. Spermathecae in 9 and 10. Sperm sacs in 9, 11, and 12. Longitudinal partitions of the calciferous gland, 70 to 75 in number. Septa, 6/7–9/10, strongly, and 10/11–14/15, moderately, thickened.

This species is widely distributed in Europe and has been reported in North America, from Massachusetts, New York, Maine, Connecticut, Maryland, District of Columbia, Michigan, Colorado, California, Illinois, and Ohio. In Missouri it has been collected from St. Louis, Franklin, Marion, Lewis, Adair, Cooper, and Cape Girardeau counties. This species has not been listed in Missouri heretofore.

**Lumbricus rubellus** Hoffmeister, 1843

Length 7–13 cm. Somites 90–145. Color, reddish brown or deep violet; color more pronounced on the anterior dorsal surface. The clitellum covers somites 27–32. Tubercula pubertatis on 28–31. The prostomium is tanylobic. Setae closely paired. The oviducal pore is on somite 14, slightly dorsal to b. Spermiducal pores on 15. Spermathecal pores on 9/10 and 10/11, in line with cd. Sperm sacs in 9, 11, and 12. There are about 60 longitudinal partitions of the calciferous gland. Septa 6/7–8/9 somewhat thickened; others but very little, with the exception of those in the regions of the sperm sacs. Spermathecae are in 9 and 10.

This species is usually collected among debris. It is widely distributed in Europe and Siberia, and in North America it has been reported from Newfoundland, California, Oregon, Washington, Michigan, and Ohio. It has been collected in St. Louis county. This species has not been listed in Missouri heretofore.

Genus **Helodrilus** Hoffmeister, 1845

The species of this genus are distinguished by the absence of special sperm vesicles enclosing the spermaries and the spermiducal funnels.

The following are subgenera for North America: *Eiseniella*, *Eisenia*, *Allolobophora*, *Dendrobaena*, *Bimastus*. A description of each of these will be given under the subgeneric heading.

Subgenus **Eiseniella** Michaelson, 1900

Michaelsen (Oligochaeta in "Das Tierreich") considered *Eiseniella* a genus. This group was later reduced to subgeneric rank by Michaelsen in 1910 when considered *Eiseniella* very closely related to the subgenus *Eisenia*. So closely related are they that the only character used as a basis for their separation is the somewhat shorter gizzard which is chiefly restricted to the 17th somite in *Eiseniella* and ordinarily involves, in addition, more of the 18th in others. The position of the oviducal pores is also a significant character. Smith states that the American material of *Helodrilus tetraedrus*, *H.t hercynia*, and Eisen's *Tetragonurus pupa* has shown that in every specimen examined the oviducal pores open slightly dorsal to b, as they do in all the Lumbricidae. *Eiseniella* differs from other subgenera, except *Eisenia*, in having the pores of the paired spermathecae between the setae line d and the mid-dorsal line.

**Helodrilus** (**Eiseniella**) **tetraedrus** (Savigny) 1826,
forma **typica** Michaelsen

Length of specimens 4–6 cm. Somites 80–100. Color usually some variable shade of brown. Prostomium epilobic. Setae closely paired. Clitellum situated on somites 22 or 23–26 or 27. Tubercula pubertatis on 23–25, seldom on 26. First oviducal-pore on 4/5. Spermiducal pores on 13. Oviducal pores on 14th somite, usually situated mesad of a. The spermathecal pores on 9/10 and 10/11 between d and mid-dorsal line. Septa 7/8–11/12 are slightly thickened.

Calciferous gland poorly developed compared to other Lumbricidae and longitudinal partitions narrow. Sperm sacs in 9–12. Spermathecae on dorsal side, chiefly in 9/10 and 10/11.

*Helodrilus tetraedrus*, forma *typica* usually found in water-soaked banks of streams, lakes and ponds. It has been collected in Europe and in many parts of the world where Europeans have settled. In the United States it has been reported in Indiana, Pennsylvania, California, Michigan, Colorado, Washington, Illinois, and Ohio. This species has been collected in the following Missouri counties: Jackson, St. Louis, Cape Girardeau, Scott, Jackson, Phelps, Osage, Adair, Shelby and Boone. This species has not been listed in Missouri heretofore.

**Helodrilus tetraedrus** forma **hercynia** (Michaelsen), 1890

This variety is very similar to that of *Helodrilus*, f. *typica* except that the spermiducal pores are on 15 instead of 13.

It has been collected in the same habitats as *typica*. In the United States it has been reported in Illinois and Ohio. The writer has collected this species from St. Louis and Cape Girardeau counties. It has not been listed in Missouri heretofore.

Subgenus **Eisenia** Malm, 1877

The characters used as a basis for separation of the *Eiseniella* from *Eisenia* are as follows: shorter gizzard, which is chiefly confined to the 17th somite in *Eiseniella*, while in *Eisenia* it ordinarily involves more of the 18th; the location of the spermathecal pores, which are very near the mid-dorsal line, slightly dorsal to d. The location of the spermathecal pores are alike in both *Eiseniella* and *Eisenia*, and this character alone separates the subgenus from all others except *Eiseniella*. The oviducal pores open slightly mesad to a, instead of slightly dorsal to b, as in all the other subgenera, with the exception of *Eiseniella*.

**Helodrilus (Eisenia) foetidus** (Savigny), 1826

Length of specimens collected was 5–15 cm. Somites 75–125. This worm has very conspicuous and characteristic coloring, due to transverse purple brownish bands on middle area of somites, and alternating with an almost pigmentless inter-segmental area. Pigment is also lacking on the lateral area of 9–11. Prostomium epilobic 1/2. Setae closely paired. Clitellum begins on 24, 25, 26–32. Tubercula pubertatis on somites 28–30 or 31. First dorsal pore on 4/5. Spermiducal pores on 15, between b and c, and not close together. Oviducal pores on 14, slightly in a dorsal position from b. Spermathecal pores on 9/10 and 10/11, near the mid-dorsal line. Sperm sacs are in 9–12. Spermathecae usually in 9 and 10 and in close relation to septa 9/10 and 10/11. They may be posterior in position to the septa.

This species is the one generally used for experimental biological work and appears in such literature under the name *Allolobophora foetida*. This is due to the fact that it can readily be obtained in all seasons of the year, as it finds very favorable conditions in manure, near stagnant pools, in decayed vegetation, especially where a great deal of moisture is present.

*Helodrilus foetidus* is widely distributed in various parts of the world. In North America, where it is very abundant, it has been collected along the Atlantic and Pacific coasts, in the Mississippi Valley, Rocky Mountain Region, and Gulf States. In Missouri it has been found in the following counties: Scott, Cape Girardeau, Ste. Genevieve, St. Francois, Jefferson, St. Charles, Macon, Adair, Knox, Marion, Jackson, Stoddard, and Bollinger.

**Helodrilus (Eisenia) roseus** Savigny, 1826

Length 4–8 cm. Somites 130–150. Color pale red; the body walls without pigment. Prostomium epilobic 1/2. Setae closely paired. Clitellum begins on somites 25–32 and may involve 24 or 33. Tubercula pubertatis, usually 29–30, occasionally on 30–31. Glandular papillae may have modified genital setae, often including one or more setal bundles of 9, 10, 12, or 13. First dorsal pore on 4/5. Spermiducal pores on 15 near b. Oviducal pores on 14, slightly dorsal to b. Spermathecal pores on 9/10 and 10/11 situated near the mid-dorsal line. Septa 6/7–9/10, thickened considerably; others to 14/15, slightly. Sperm sacs in 9–12. The spermathecae are on the dorsal side of 10 and 11 with short ducts.

This species is widely distributed in Europe and in various parts of the world. In the United States it has been reported in New York, Georgia, Indiana, Louisiana, Arizona, California, Maine, and Ohio. It was found in Ste. Genevieve, Jefferson, and Cape Girardeau counties. This species has not been listed in Missouri heretofore.

Subgenus **Allolobophora** Eisen, 1874

Michaelsen, 1900a, 480, gives the following description for the subgenus *Allolobophora:* "Prostomium is usually epilobic, very seldom tanylobic. Setae are more or less closely paired. Spermiducal pores on 15. Spermathecal pores consisting of two or three pairs in the setal line cd. Gizzard including more than one segment. Testes are seminal funnel free; 4 pairs of sperm sacs in 9–12. Sperm sacs of 10 as large as those of 9 (always?)."

Smith (1917) adds the following: "The setae are more or less closely paired. Sperm sacs, four pairs in 9–12; those of 12 approximately as large as those of 9."

**Helodrilus (Allolobophora) caliginosus,**
forma **typica,** Savigny, 1826

Length 5–20 cm. Somites 100–250. The color of the anterior dorsal surface is brown-red, which is quite variable in intensity in different specimens. Prostomium epilobic. Setae closely paired, those of the lateral pairs especially. Clitellum situated on somites 27–34 or 35. Tubercula pubertatis on 31 and 33. There are conspicuous glandular papillae which surround the ventral side setae 9, 10, 11 and are usually present on 32–34 and may be absent on 28 and 30. First dorsal pore on 9/10. Spermiducal pores on 15, rather more than half way from b to c. Oviducal pores are on somite 14, slightly dorsal to b. The spermathecal pores on 9/10 and 10/11 are in line with the dorsal

bundles. The septa of 6/7–9/10 are very strongly thickened, while those of 5/6 and 11/12–14/15 are less so. The longitudinal partitions of calciferous glands are about 55–56 in number. Sperm sacs are in somites 9–12. Spermathecae are within the septa of 9/10 and 10/11 and do not extend freely into the somite cavities.

This species was found in Bollinger, St. Louis, Scott, Cape Girardeau, and Boone counties. It has not been listed in Missouri heretofore.

**Helodrilus (Allolobophora)** forma **trapezoides** Duges, 1828

This variety differs from f. *caliginosus* only in the position of the tubercula pubertatis. In *typica* they are on 31 and 33, while in *trapezoides* they are continuous on 31 to 33 inclusive.

*Helodrilus caliginosus trapezoides* is by far the most abundant and has a very wide distribution in the United States. It is listed for the following counties: St. Louis, Jefferson, Ste. Genevieve, St. Francois, Perry, Cape Girardeau, Scott, Bollinger, Stoddard, Mississippi, and Boone. This species has not been listed in Missouri heretofore.

**Helodrilus (Allolobophora) chloroticus** Savigny, 1826

Length 5–7 cm. Somites 80–125. Color more or less greenish. Prostomium epilobic. Setae closely paired. Clitellum on somites 29–37. Tubercula pubertatis consists of three pairs of succer-like elevations on somites 31, 33 and 35. First dorsal pores on 4/5. Spermiducal pores on 15, between b and c. Oviducal pores on 14, slightly dorsal to b. Spermathecal pores on 8/9–10/11, in line with the dorsal bundles. Septa 6/7–13/14 are moderately thickened; those from 9/10 diminish gradually toward the posterior. Sperm sacs in 9/12. Spermathecae are in 9, 10, and 11, extending freely into the somite cavities with the ducts of moderate length.

This species is widely distributed in Europe and various parts of the world. In North America it has been reported from Greenland, North Carolina, Vancouver Island, California, Mexico, Guatemala, District of Columbia, Indiana, Colorado, and Ohio. It has been collected in St. Louis, Macon, and Cape Girardeau counties. This species has not been listed in Missouri heretofore.

Subgenus **Dendrobaena** Eisen, 1874

The characters for this subgenus are as follows: Setae widely paired or separate. Spermathecal pores on 9/10 and 10/11 on setae lines of c and d. There are three pairs of sperm sacs in 9, 11, and 12.

Smith (1917) states that some of these characters are combined with others belonging to other subgenera, breaking the dividing line and making classification difficult.

**Helodrilus (Dendrobaena) subrubicundus** Eisen, 1874

Length 5–8 cm. Somites 80–125. The anterior dorsal surface is of a variable red color. Prostomium epilobic 2/3. Setae widely paired. Clitellum on somites 26–31, and may invade 25 or 32. Tubercula pubertatis on somites 28–30. First dorsal pore on 5/6. Spermiducal

pores on 15, between b and c. Oviducal pores on 14, slightly dorsal to b. Spermathecal pores on 9/10 and 10/11, in the setal line c. Septa 7/8 and 8/9 moderately thickened, 6/7, 9/10, 13/14, and 14/15 slightly thickened. Sperm sacs in 9, 11, 12. Spermathecae in 9 and 10, free in somite cavities, with very short ducts which enter the septa near the body wall.

This species is widely distributed in Europe and various parts of the world. It has been reported in North America from Newfoundland, California, Colorado, Canada, Illinois, and Ohio. Collections were made from St. Louis, Cape Girardeau, Macon, Marion, Osage, Randolf, and Adair counties. This species has not been listed in Missouri heretofore.

### Subgenus **Bimastus** (H. F. Moore), 1893

In this subgenus the tubercula pubertatis are indistinct or lacking. There are about two pairs of sperm sacs, which are in somites 11 and 12. The spermathecae are normally developed. The clitellum in most of the species under this subgenus does not extend posterior to 32.

### **Helodrilus** (**Bimastus**) **giesseleri** var. **hempeli** Smith, 1915

Length 4–7 cm. Somites 100–110. Color of dorsal half of body red-brown, while the ventral half lacks pigment. Setae closely paired. Clitellum situated on 22–29 and sometimes part of 30. Tubercula pubertatis lacking. First dorsal pore on 5/6. Spermiducal pores on 15, slightly dorsal to b. Oviducal pores on 14. Longitudinal partitions of calciferous gland about 40 in number. Sperm sacs are in somites 11 and 12. Spermathecae are lacking.

This species is usually found in decayed leaf material, under logs and rotten wood. It has been collected in Florida, Illinois, Kansas, Texas, Indiana, and Ohio, and in the following counties in Missouri: Greene, Jackson, Clinton, Cape Girardeau, Ste. Genevieve, Perry, St. Louis, Boone, Macon, Cooper, and Marion. This species has not been listed in Missouri heretofore.

### **Helodrilus** (**Bimastus**) **zeteki** Smith and Gittins, 1915

Length 10–12 cm. Somites 110–140. Color of anterior dorsal surface purple brown. Prostomium epilobic, 1/3–1/2. Setae closely paired. Clitellum on 27–37, and extends ventrally enough to include the ventral setae of 30–36. Tubercula pubertatis entirely lacking. First dorsal pore on 5/6; spermiducal pores on 15, slightly dorsal to b. Oviducal pores thickened (on 14) slightly dorsal to b. Septa 6/7–12/13 are slightly thickened, those of 13/14 more strongly so. There are about 60–64 partitions of the calciferous gland. Sperm sacs in 11 and 12. Spermathecae lacking.

It has been collected from the following states: Michigan, Indiana, Illinois, and Ohio; and from the following Missourian counties: Cape Girardeau, Jefferson, Osage, Marion, and Adair. This species has not been listed in Missouri heretofore.

**Helodrilus (Bimastus) tenuis** Eisen, 1874

Length, 4–8 cm. Somites 90–100. Color of the anterior dorsal surface rose red, rest of the body decided pale color. Prostomium epilobic 2/3. Setae widely paired. The clitellum is situated on somites 26–31. Tubercula pubertatis are indistinct and often lacking; when present usually on 29 and 30. The ventral setae of the sixteenth somite are borne on glandular papillae. First dorsal pore on 5/6. Spermiducal pores on 15, between b and c, situated on glandular elevations. Oviducal pores on somite 14, slightly dorsal to b. Septa are slightly thickened throughout. There are about 40 longitudinal partitions of the calciferous gland. Sperm sacs in 11 and 12. Spermathecae not fully developed.

*Helodrilus tenuis* is most abundantly found under decayed leaf mold and decayed timber. It has been collected in almost all parts of Europe, Asia, and South America. In North America it has been collected in Mexico, Alaska, Vancouver Island, Canada, California, New York, Maine, Indiana, Michigan, Colorado, Washington, Bering Island, Illinois, and Ohio.

This species was taken from a greenhouse in Cape Girardeau, Missouri. Later specimens were sent to the author from St. Louis, St. Charles and Marion counties and it is here listed in Missouri for the first time.

**Octolasium lacteum** Orley, 1881

Length, 5–16 cm. Somites 100–170. A few of the anterior somites are pink in color; posterior end is pale, while remainder of body, except clitellum, is blue-gray. Prostomium usually epilobic, 1/2–2/3; occasionally tanylobic. Setae widely paired. Clitellum on somites 30–35. Tubercula pubertatis on 31–34. First dorsal pore on 8/9, 9/10, or 10/11, in line with c and d. The septa 6/7–8/9 are slightly thickened, 9/10–13/14 are less thickened. There are about 45 longitudinal partitions of the calciferous gland. The calciferous gland communicates at its anterior end with the esophagus. The spermaries and the spermiducal funnels in 10 and 11, included in sperm vesicles. The spermaries are in 9–12; those of 9 and 10 being quite different in form and appearance from those of 11 and 12, which resemble those commonly found in the Lumbricidae. The sperm sacs of 9 and 10 are digitiform and each has a definite lumen extending through the greater part of the length.

This species is found in greater quantity under decayed leaf mold, compost heaps and logs, and in very rich soil. It is widely distributed in Europe and in various parts of the world. It has been collected in Illinois, California, Mexico, Indiana, Colorado, and Ohio. This species has not been listed in Missouri heretofore. It has been found in Cape Girardeau and Miller counties.

Genus **Diplocardia** H. Garman, 1888

Setae paired, absent from segment 19 on which the male pores are present; spermiducal pores on 18 and 20. Clitellum, 13–18. Two

pairs of prostate pores on both somites adjacent to the male pores. There are three pairs of sperm pouch pores, the posterior one on the 9th somite. Two muscular crops, mostly in the 5th and 6th, rarely in the 6th and 7th somites; separated, pouch-shaped calciferous glands. Esophageal pouches absent. Two pairs of free testicles and sperm funnels.

**Diplocardia communis** Garman, 1888

Length 18–30 cm. Number of somites 125–160. Color of the anterior dorsal surface pale flesh. Setae widely separated. Clitellum saddle-shaped, situated on somites 13–18 inclusive. Prostate pores on somites 18 and 20. Spermiducal pores on somite 19 and spermathecal pores in somites 6/7, 7/8 and 8/9. Sperm sacs in 9 and 12.

This species was the first genus to be described. It differs from the others in having a double dorsal blood vessel throughout the entire length of the body. (Smith (1918) states that this species is abundant in the prairie soils of Illinois. The author (1928) listed it in Ohio. It is widely distributed in Southeast Missouri in which it has been heretofore listed and has been taken from St. Louis, Cape Girardeau, Scott, Bollinger, Jefferson, Pike, Marion, Jackson, Lafayette, Boone, Macon, Adair and Franklin counties.

**Diplocardia riparia** Smith, 1895

Length, 20–27 cm. Somites 135–160. Color of the anterior dorsal surface dark brown, much darker than in *D. communis*. Setae in four pairs and wide apart. Clitellum saddle-shaped, on 12–18, of a dull copper color, usually slightly developed and sometimes absent. Prostate pores on somites 18 and 20. Spermiducal pores on somite 19, near anterior margin of somite. Two pairs of spermathecae, one pair in each somite of 18 and 19, with the external openings at the anterior margins of those somites and in line with the inner rows of setae. Sperm sacs in 9 and 12. Ovaries are in somite 13, and female pores in somites 14. Spermathecal pores on somite 7/8 and 8/9.

Smith (1915) states that this species is plentiful in the rich soil bottom land forests of Illinois. The author in 1928 listed it in Ohio and lists it now for the first time in Missouri from the following counties: Cape Girardeau, Perry, and St. Louis.

**Diplocardia singularis** Ude, 1895

Length, 5–10 cm. Number of somites, 90–120. Anterior dorsal surface flesh color. Clitellum on somites 13–18, inclusive, and of the cingulum type. Prostate pores on somites 18 and 20. Spermiducal pores on somite 19, and the spermathecal pores on somites 6/7, 7/8 and 8/9. Sperm sacs in 9 and 12.

Smith (1915) lists this species as being quite common in the upland regions of Illinois. The author, 1928, lists it in Ohio. This species has not been listed in Missouri heretofore. It has been collected in St. Charles, St. Louis, Cape Girardeau, Scott, and Ste. Genevieve counties.

BIBLIOGRAPHY

**Beddard, Frank E.** 1895. A Monograph of the Order Oligochaeta. Oxford, Clarendon Press.

**Michaelsen, W.** 1900a. Oligochaeta. Das Tierreich. 10 Lief XXIX, Berlin.

1920. Lumbricidae. Systematic Account. Zool. Jahrb. Abth.

**Olson, Henry W.** 1928. The Earthworms of Ohio: With a Study of Their Distribution in Relation to the Hydrogen-ion Concentration, Moisture, and Organic Content of the Soil. Ohio Biological Survey, Vol. IV, No. 2, Bull. No. 17, pp. 47–90, 1928.

1933. Two Species of Earthworms New for Ohio. Ohio Journal of Science, Vol. XXIII, No. 3, pp. 192–4.

**Smith, Frank.** 1915. Two New Varieties of Earthworms, With a Key to Described Species in Illinois. Bull. Ill. State Lab. Nat. Hist., 10: 551–559.

1917. North American Earthworms of the Family Lumbricidae in the Collections of the United States Natural History Museum. No. 2174. Proceedings of the U. S. Natural Museum, Vol. 52, pp. 157–182.

1928. An Account of Changes in the Earthworm Fauna of Illinois and a Description of One New Species. Ill. Div. of Natural History Survey, Vol. XVII, Art. X.

## BOOK NOTICES

### Children of Tomorrow

The principles and applications of eugenics are presented here in the form of questions and answers. The 371 questions and their well-thought-out answers cover rather completely the applications of eugenics to the population question, the individual, and the public. The presentation is objective in so far as it can be made so, and is free from objectionable propagarda and maudlin sentiment. The author, being a distinguished student of environment, as well as of heredity, approaches the problem with a broad viewpoint, unobscured by wishful thinking. The book can be well recommended to the general public.—L. H. S.

**Tomorrow's Children,** by Ellsworth Huntington. x+139 pp. New York, John Wiley and Sons, 1935. $1.25.

### Learning Botany

This Workbook is designed for use in classroom discussions in the presence of materials. A majority of the thirty-three exercises are devoted to a consideration of the vegetative and reproductive phases of the typical flowering, seed-bearing plant. This is followed by a survey of the plant kingdom. The physiological aspect receives the greatest emphasis although all the major divisions of the field of Botany are adequately presented.

The book contains suggestions and questions regarding observations to be made. It provides aid to the recording of observed data in the form of graphs, blank charts and an extensive set of diagrams. Data needed in certain learning situations are supplied as well as problems calling for use of data in new situations. There are plans for summaries, and problems and questions leading to a recalling and weaving together of what has been accomplished. Subject matter is presented as a means to the teaching of the student rather than as an end in itself. The student is aware of his continuous mental development, and may acquire a true scientific attitude by becoming acquainted with and making use of the scientific method.—R. A. Dobbins.

**Workbook in General Botany,** by E. N. Transeau, H. C. Sampson, and L. H. Tiffany. v+160+73 pp. Looseleaf; lithographed by Edwards Brothers, Inc., Ann Arbor, Michigan. 1935. $1.75.

### Termites and Termite Control

The first edition of this outstanding report of "The Termite Investigations Committee" was published in January, 1934. Since then the authors of the various chapters have continued their researches and have reported their results in the second edition, revised, which has been recently published. No change has been made in chapter 46, which contains the general recommendations for the control of termite damage. The major additions are (1) in Chapter 2, a paragraph on the relation of moisture to the production of arsine from wood preservatives containing arsenic; (2) in chapter 4, additional experimental data bearing on the sensitiveness to moisture of the Pacific Coast species of termites; (3) in chapter 9, experimental evidence that termites are dependent upon fungi for the nitrogenous elements of their diet to such an extent that in the absence of fungi their normal growth is retarded; (4) in chapter 24, an experimental investigation of caste differentiation in termite communities; (5) in chapter 34, changes regarding Bruce Preservative, Halowax, and Wolman Salts; (6) in chapter 36, substitution of the 5th Progress Report of the International Termite Exposure Test for the 4th Progress Report; (7) in chapter 41, a statement of the essential features of the Standard Biological Test; also, some Standard Biological Tests on two wallboards, and an experimental test of the toxicity and penetration throughout the test block of refined creosote in a solvent; and (8) in the added chapter, 57, a discussion of the association of termites with arsine-producing fungi. An excellent subject index has been added, which was one criticism of the first edition.

The writers are indeed to be congratulated on this second edition. It is a most complete report and serves as a noteworthy example of what can be accomplished when scientists, engineers, and corporations co-operate in solving such problems. Every contractor, architect, and engineer should possess a copy. As a scientific reference on the subject, it is invaluable for entomologists and teachers of biology.—R. H. DAVIDSON.

**Termites and Termite Control,** by Charles A. Kofoid et al. 795 pages, 182 figures. Second Edition, Revised. Berkeley, University of California Press, 1936. $5.00.

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### Procedure in Taxonomy

This little book is the result of a symposium on taxonomy by graduate students and professors at Stanford University. It was prepared "for the purpose of supplying the student as well as the professional systematist with (1) a clear-cut and comprehensive statement of the principles of taxonomy; (2) the International Rules of Zoological Nomenclature; (3) Summaries of Opinions Rendered to the present date; (4) a complete index—the only index of the Rules and Summaries ever published."

The original material in the book is very brief, covering only 25 pages. The chapter headings are: Introduction, Systematic Categories, Types, Descriptions of New Species, Specific Names, Synonymy, Storage of Type Material, and Latin Terms and Abbreviations. The chapters on Types, Synonymy, and Latin Terms and Abbreviations are particularly valuable. The chapter on Synonymy is concerned with methods of listing synonymy, and contains suggestions which, if followed by all taxonomists, would eliminate a great deal of confusion. The chapter on Descriptions of New Species contains very little of value to the zoologist; the examples given are from the field of paleontology. The very important matter of drawings is barely mentioned. The chapter on Specific Names contains some good suggestions for the selection of new names, but lacks a discussion of the Law of Priority as it applies to the use of specific names. A subject completely overlooked in this book is the matter of constructing analytical keys, which is certainly an important phase of taxonomic procedure.

The brief, concise discussion, as far as it goes, and the copy of the Rules and Opinions, make this book a handy one for any paleontologist or zoologist venturing into the field of taxonomy.—D. J. BORROR.

**Procedure in Taxonomy, Including a Reprint of the International Rules of Zoological Nomenclature with Summaries of Opinions Rendered to the Present Date,** by Edward T. Schenk and John H. McMasters. vii+72 pages. Stanford University, California, Stanford University Press, 1936. $2.00.

### Atoms

This book, which originally appeared in German under the title "Moderne Physik," is an excellent exposition of the theoretical development of modern physics. The book is written in a style which makes it attractive reading for the student not too far advanced in his graduate work. A delightful feature is the set of appendices at the end of the book where rigorous proofs to many of the hypotheses stated are given. The English edition has been thoroughly modernized and brought up to date with the developments of recent years.—H. H. NIELSEN.

**Atomic Physics,** by Max Born. xii+352 pp. New York, G. E. Stechert and Co., 1936.

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### Our Enemy the Termite

In order to properly cope with the termite or so-called "white ant," the public should be better informed on this subject. One means of obtaining a better understanding of this very interesting group of insects is by reading this book written by Dr. Snyder. He presents in readable style, a very interesting but concise scientific discussion of all phases of the termite problem.

The first six chapters discuss the place of termites among insects; the different species of termites; their life history and the caste system; their physiology and behavior; their food habits and guests of the termite colony. The four remaining chapters discuss the damage done by termites and methods of control. Practical suggestions are given for building termite-proof houses and for saving structures already infested. Various methods of control now being used are discussed and fraudulent ones exposed.

An appendix is included which contains recommendations for city building codes, for insuring protection against termites and decay, a model tally sheet for recording termite damage by building inspectors, and specifications for an agreement between the house owner and a contractor undertaking to remedy termite damage to buildings.

A table of contents, an index, and a glossary of technical terms are included. Many illustrations aid in the presentation of material. Large easily read type on good quality paper, combined with simple presentation of subject matter make this book especially valuable to the home-owner and contractor.

R. H. DAVIDSON.

**Our Enemy the Termite,** by T. E. Snyder. 196 pp., 56 figs. Ithaca, The Comstock Publishing Co., 1935. Price, $3.00.

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### Valence

This recent book by Kronig which has appeared in the Cambridge Series of Physical Chemistry is a valuable asset to the library of any physicist or chemist. The contents, which are chiefly devoted to a discussion of the band spectra of diatomic and polyatomic molecules and their bearing upon the problems of molecular structure and chemical binding, are comprehensive, yet presented in a manner such that the book may be read by a student of chemistry or physics in his early graduate career. In a preliminary course in molecular theory where the more intimate problems are not dealt with, the book would appear to be a very suitable text.—H. H. NIELSEN.

**The Optical Basis of the Theory of Valence,** by R. deL. Kronig. viii+246 pp. Cambridge, at the University Press; New York, the Macmillan Co., 1935. $4.50.

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### Serological Reactions

This monograph, from the pen of the distinguished Nobel Prize winner, Karl Landsteiner, brings together under one cover the results of a long series of serological experiments by many workers, including the author and his associates. Critical problems involving the antigen-antibody reactions are surveyed, and various hypotheses are compared and evaluated. The antigenic properties of proteins, carbohydrates, lipoids and artificial conjugated substances are thoroughly discussed. Recent work on the chemistry of cell antigens is presented. Particularly interesting and valuable are the chapters on the specificity of cell anti-

gens, and the specificity of antibodies. Comprehensive bibliographies are included at the ends of the various chapters, although the arrangement of the references is not conducive to their most efficient use.—L. H. S.

**The Specificity of Serological Reactions,** by Karl Landsteiner, M. D. vii+178 pp. Springfield, Illinois, Charles C. Thomas, 1936. $4.00.

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### Quantum Mechanics

This book is an attempt to replace the physical models, of which the experimental physicist was earlier so fond, with the quantum mechanics. Wherever it is possible graphical methods are employed. Such problems as the formation of molecules, valence bonds and electrons in crystals receive especial attention, while the last chapter is devoted to the topic of perturbation theory as applied to physical problems and to a discussion of the description of physical events. The book can be very sincerely recommended to the student of physics and chemistry.

H. H. NIELSEN.

**Elementary Quantum Mechanics,** by R. W. Gurney. vii+159 pp. Cambridge, at the University Press; New York, the Macmillan Co., 1934. $2.35.

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### The Meaning of Chemistry

The sixth edition of this fine work has been revised by Glasstone, and is a worthy successor to the previous editions. The volume is an extraordinarily well written introduction to the subject of chemistry and chemical research. It begins with a discussion of such simple things as the nature and purpose of laboratories, the description and use of apparatus, and the general meaning of chemistry. For the non-technical reader (for whom the book was written) this is especially worth while, since a knowledge of such things is mistakenly taken for granted in most chemistry books written for the layman. One by one the underlying principles of chemistry are clearly developed, until the reader is prepared to enter the field of practical applications. These are presented in most readable style. The last section deals especially with organic chemistry. New material in this edition includes up-to-date discussions of valency, atomic structure, transmutation and disintegration of elements, artificial radioactivity, heavy hydrogen, synthetic rubber, artificial plastics, vitamins, hormones, and nitrogen fixation. The book is most highly recommended to those interested in acquiring an understanding of the work of the chemist.—L. H. S.

**Chemical Discovery and Invention in the Twentieth Century,** by Sir William A. Tilden. Sixth edition, revised by S. Glasstone. xvi+492 pp. New York, E. P. Dutton & Co., 1936. $4.00.

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### Protoplasm

Under this title Dr. Seifriz has written a very readable book for students of biology, medicine, and related fields. The discussion considerably exceeds the bounds indicated by the title and the book would serve as a satisfactory introduction to the subject of general physiology. An adequate background of physicochemical concepts and principles is presented before the author proceeds to a discussion of the biological aspects of the subject. Both the dull finality of scientific dogmatism and the inconclusiveness of too encyclopedic presentation have been skillfully avoided. A few mis-statements will be noted by a careful reader, but on the whole the book is commendably free from factual errors. The reviewer's principal criticism is that the last few chapters do not seem to maintain quite the high standard set by most of the book. A fairly extensive selected bibliography, classified according to chapter headings, is appended to the discussion.—B. S. MEYER.

**Protoplasm,** by William Seifriz. 584 pp. New York, McGraw-Hill Book Company, 1936. $6.00.